US009158095B2

(12) **United States Patent**
Baba

(10) **Patent No.: US 9,158,095 B2**
(45) **Date of Patent: Oct. 13, 2015**

(54) **OPTICAL UNIT AND IMAGING APPARATUS**

(75) Inventor: **Tomohiko Baba**, Kanagawa (JP)

(73) Assignee: **SONY CORPORATION**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 221 days.

(21) Appl. No.: **13/583,863**

(22) PCT Filed: **Mar. 14, 2011**

(86) PCT No.: **PCT/JP2011/055922**
§ 371 (c)(1), (2), (4) Date: **Sep. 10, 2012**

(87) PCT Pub. No.: **WO2011/118434**
PCT Pub. Date: **Sep. 29, 2011**

(65) **Prior Publication Data**

US 2013/0010181 A1 Jan. 10, 2013

(30) **Foreign Application Priority Data**

Mar. 24, 2010 (JP) 2010-067968

(51) **Int. Cl.**

G02B 9/12	(2006.01)
G02B 13/00	(2006.01)
G02B 13/18	(2006.01)

(52) **U.S. Cl.**
CPC ***G02B 13/006*** (2013.01); ***G02B 9/12*** (2013.01); ***G02B 13/0035*** (2013.01); ***G02B 13/18*** (2013.01)

(58) **Field of Classification Search**
CPC G02B 9/12; G02B 9/14; G02B 9/18; G02B 9/24; G02B 9/26; G02B 9/28; G02B 9/30; G02B 9/32
USPC 359/784–792, 716
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,453,654 B2	11/2008	Shinohara	
2006/0044450 A1	3/2006	Wolterink et al.	
2010/0321794 A1*	12/2010	Hirao et al.	359/716

FOREIGN PATENT DOCUMENTS

JP	2007-219079	8/2007
JP	2008-134411	6/2008
JP	2009-251367	10/2009
WO	2008-102773	8/2008
WO	2008-102774	8/2008
WO	2008102648	8/2008
WO	2008-139657	11/2008
WO	2009004965	1/2009

* cited by examiner

Primary Examiner — Darryl J Collins
(74) *Attorney, Agent, or Firm* — Dentons US LLP

(57) **ABSTRACT**

An optical unit and an imaging apparatus including the optical unit. The optical unit includes a first lens group, a second lens group, and a third lens group, which are arranged in order from an object side to an image plane side. Further, the first lens group includes a first lens element, a first transparent body, and a second lens element, which are arranged in order from the object side to the image plane side.

15 Claims, 11 Drawing Sheets

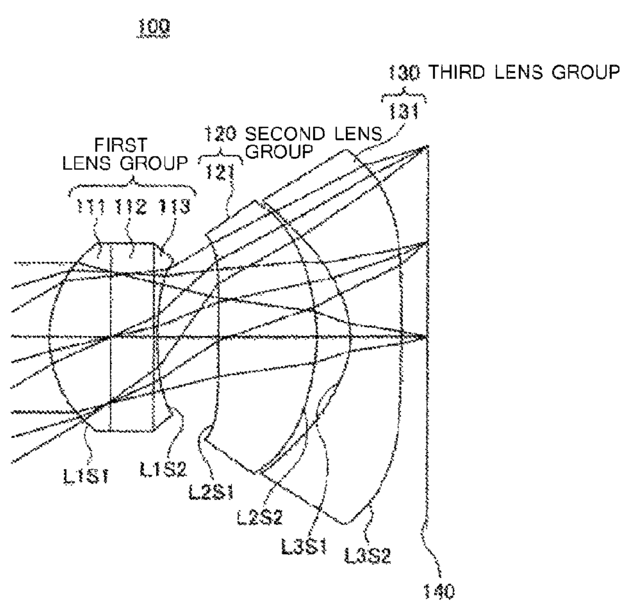


FIG. 1

EXAMPLE OF DEFOCUS CHARACTERISTICS
1/4 SIZE : Fno#2.9 : f 3.69mm TT 4.4mm

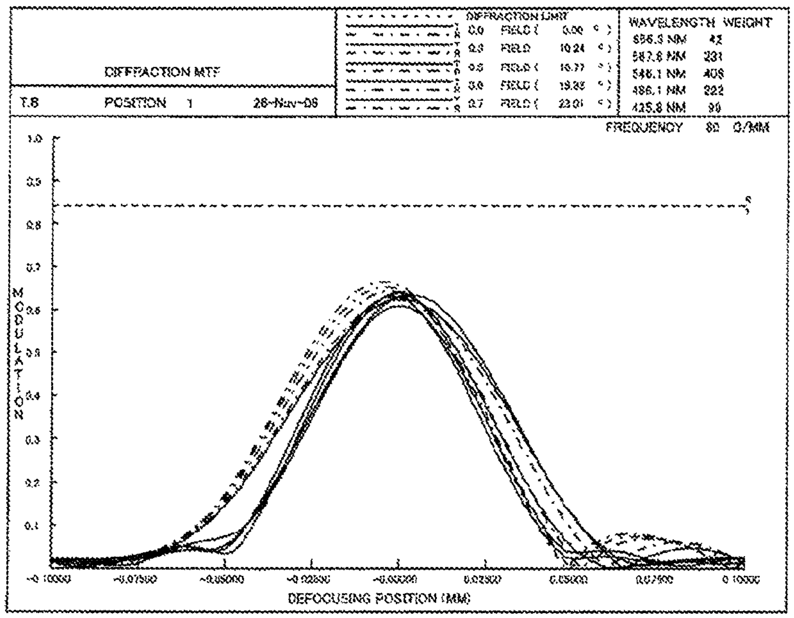


FIG. 2

EXAMPLE OF DEFOCUS CHARACTERISTICS
1/4 SIZE : Fno#2.9 : f 3.74mm TT 4.4mm

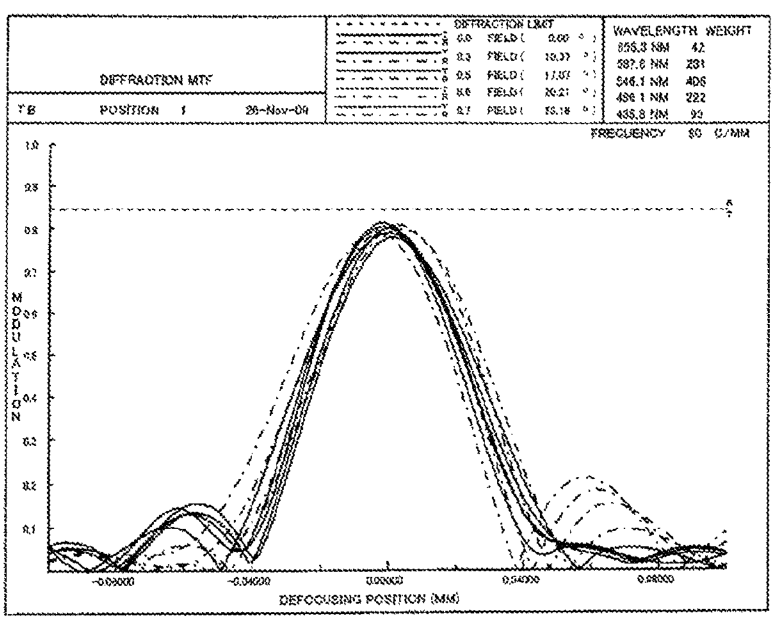


FIG. 3

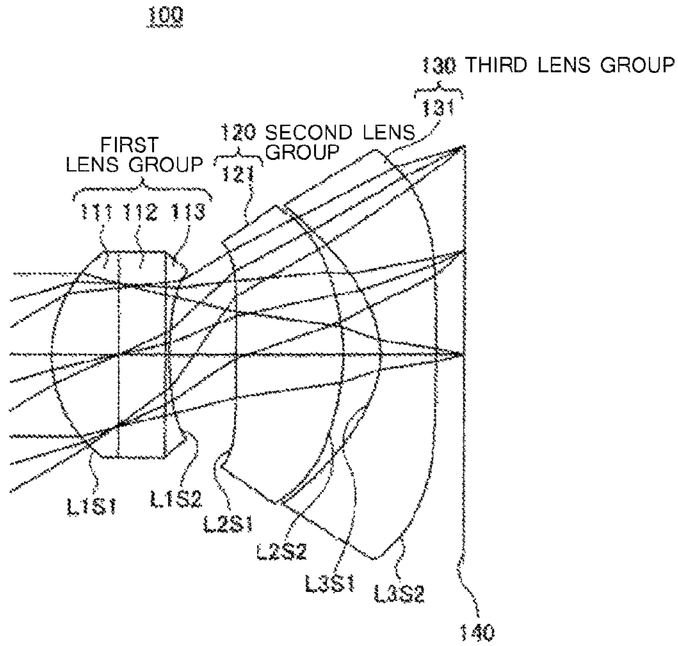

100
130 THIRD LENS GROUP
131
120 SECOND LENS GROUP
121
FIRST LENS GROUP
111 112 113
L1S1
L1S2
L2S1
L2S2
L3S1
L3S2
140

FIG. 4

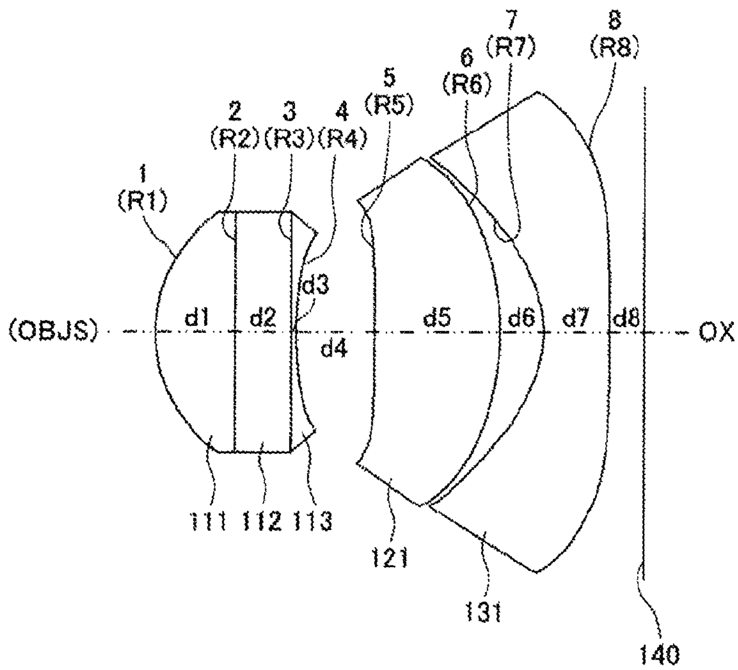

1 (R1)
2 (R2)
3 (R3)
4 (R4)
5 (R5)
6 (R6)
7 (R7)
8 (R8)
(OBJS)
d1
d2
d3
d4
d5
d6
d7
d8
OX
111 112 113
121
131
140

FIG. 5

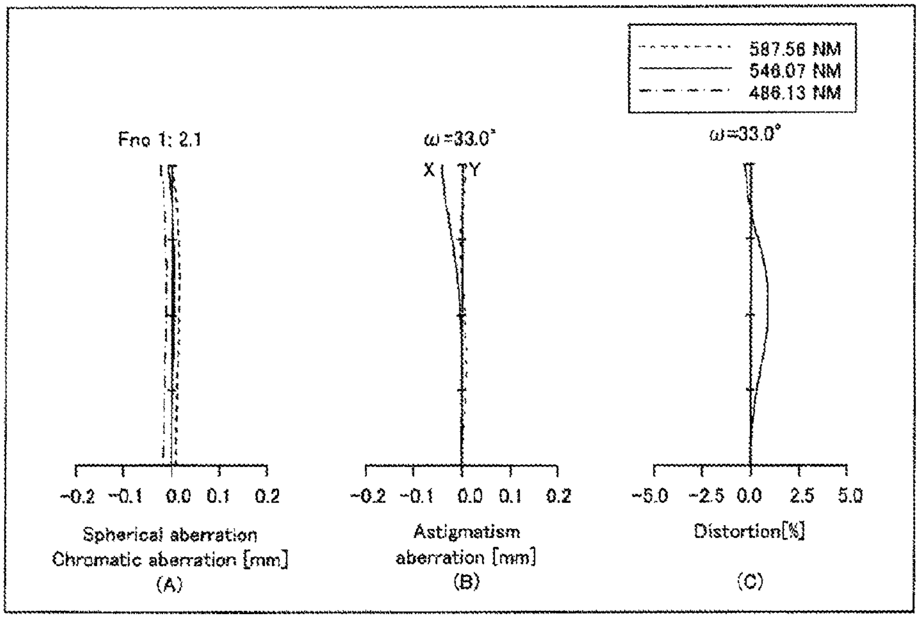


FIG. 6

DEFOCUS CHARACTERISTICS OF MTF OF EXAMPLE 1
1/4 SIZE : Fno#2.1 : f 3.64mm TT 4.4mm

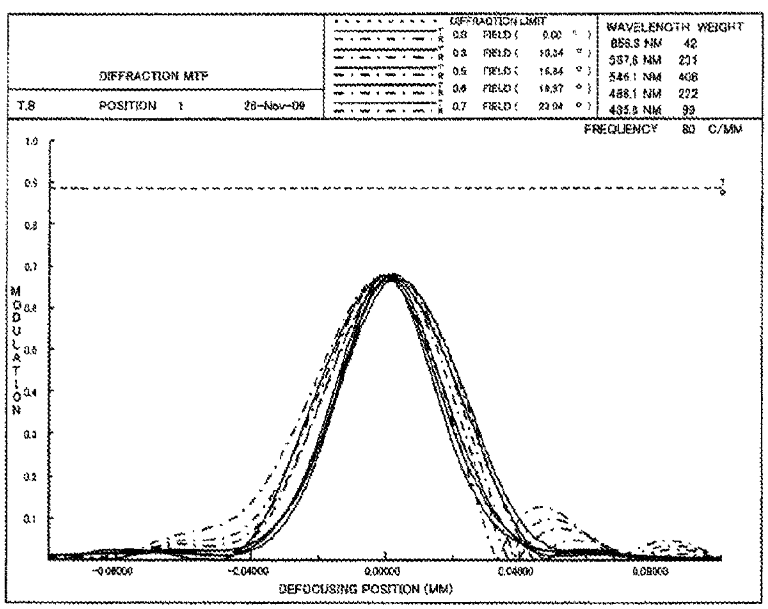


FIG. 7

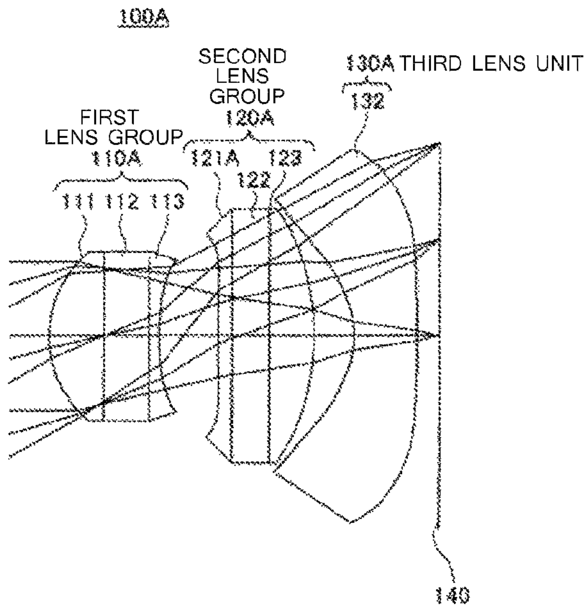

100A
SECOND LENS GROUP 120A
130A THIRD LENS UNIT
132
FIRST LENS GROUP 110A
121A 122 123
111 112 113
140

FIG. 8

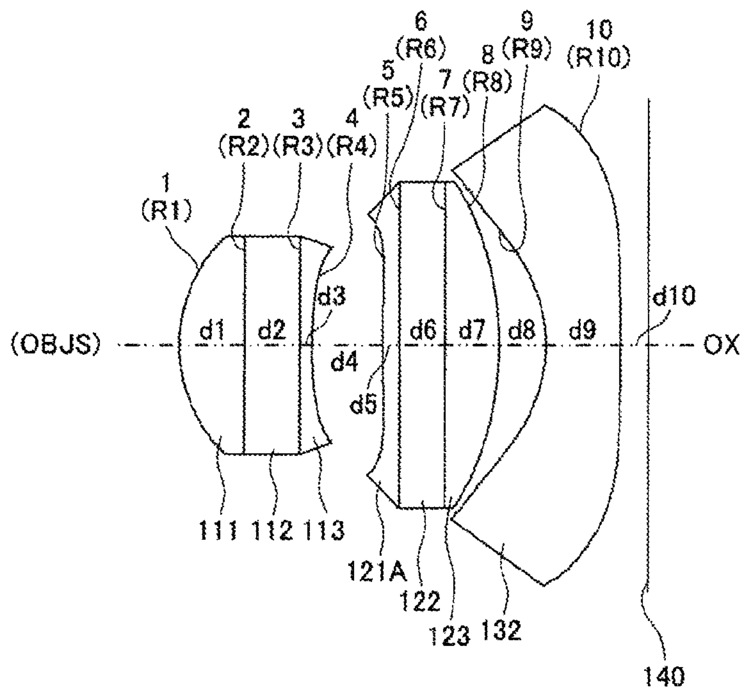

1 (R1)
2 (R2)
3 (R3)
4 (R4)
5 (R5)
6 (R6)
7 (R7)
8 (R8)
9 (R9)
10 (R10)
(OBJS)
OX
d1 d2 d3 d4 d5 d6 d7 d8 d9 d10
111 112 113
121A 122 123 132
140

FIG. 9

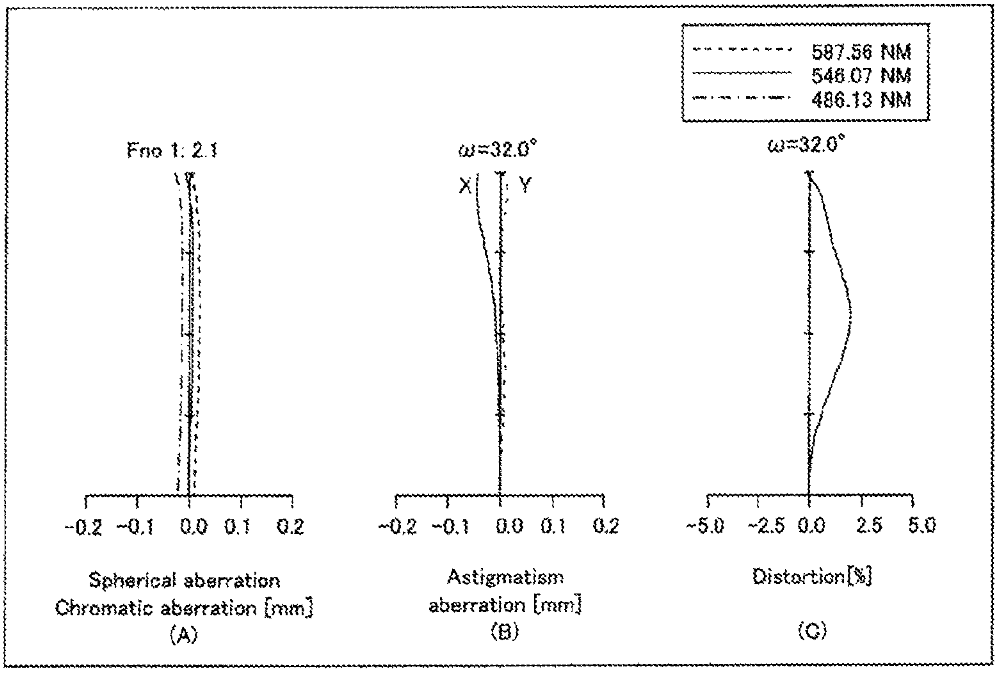

587.56 NM
546.07 NM
486.13 NM
Fno 1: 2.1
ω=32.0°
X
Y
ω=32.0°
−0.2 −0.1 0.0 0.1 0.2
Spherical aberration
Chromatic aberration [mm]
(A)
−0.2 −0.1 0.0 0.1 0.2
Astigmatism
aberration [mm]
(B)
−5.0 −2.5 0.0 2.5 5.0
Distortion[%]
(C)

FIG. 10

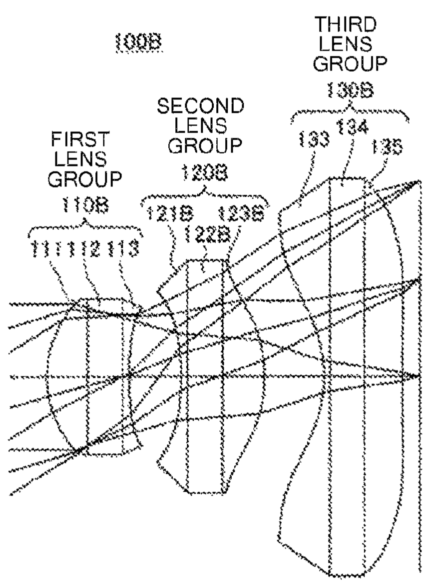

100B
FIRST LENS GROUP
110B
111
112
113
SECOND LENS GROUP
120B
121B
122B
123B
THIRD LENS GROUP
130B
133
134
135

FIG. 11

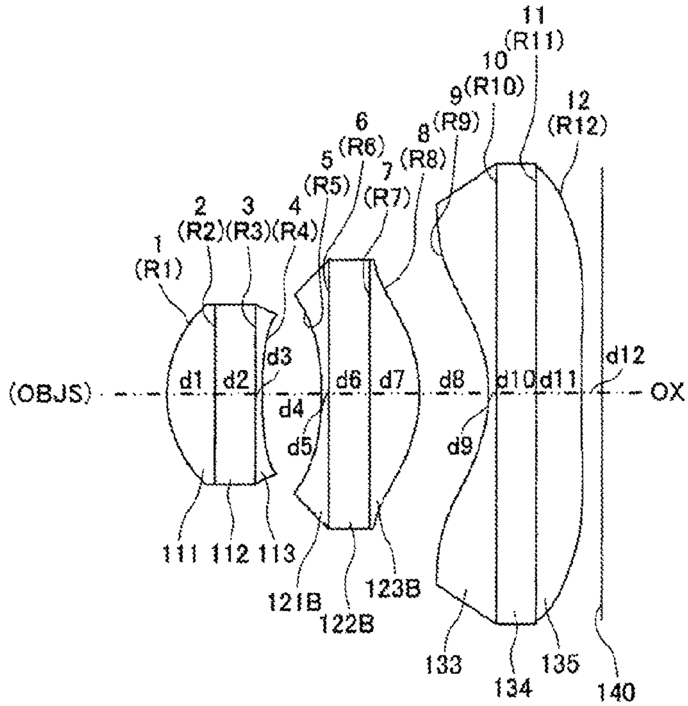

1
(R1)
2
(R2)
3
(R3)
4
(R4)
5
(R5)
6
(R6)
7
(R7)
8
(R8)
9
(R9)
10
(R10)
11
(R11)
12
(R12)
(OBJS)
OX
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
111
112
113
121B
122B
123B
133
134
135
140

FIG. 12

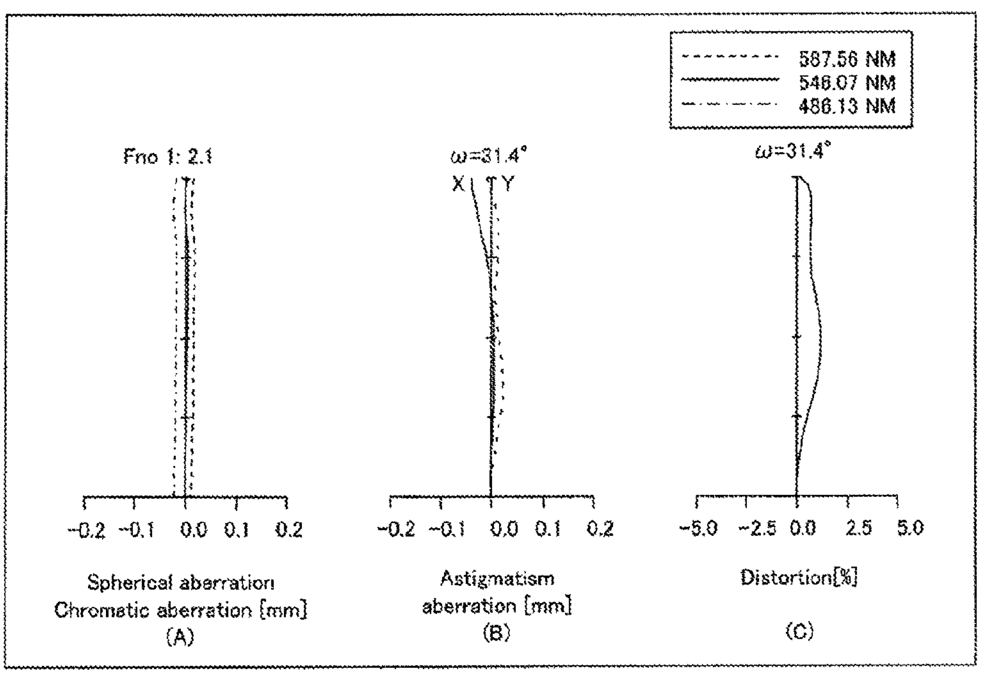

587.56 NM
546.07 NM
486.13 NM
Fno 1: 2.1
ω=31.4°
X
Y
ω=31.4°
−0.2 −0.1 0.0 0.1 0.2
−0.2 −0.1 0.0 0.1 0.2
−5.0 −2.5 0.0 2.5 5.0
Spherical aberration
Chromatic aberration [mm]
(A)
Astigmatism
aberration [mm]
(B)
Distortion[%]
(C)

FIG. 13

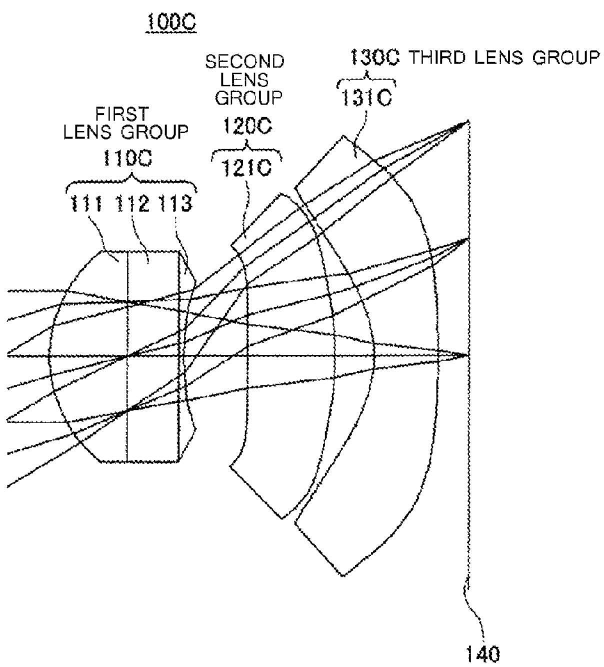

100C
SECOND LENS GROUP
130C THIRD LENS GROUP
131C
FIRST LENS GROUP
120C
110C
121C
111 112 113
140

FIG. 14

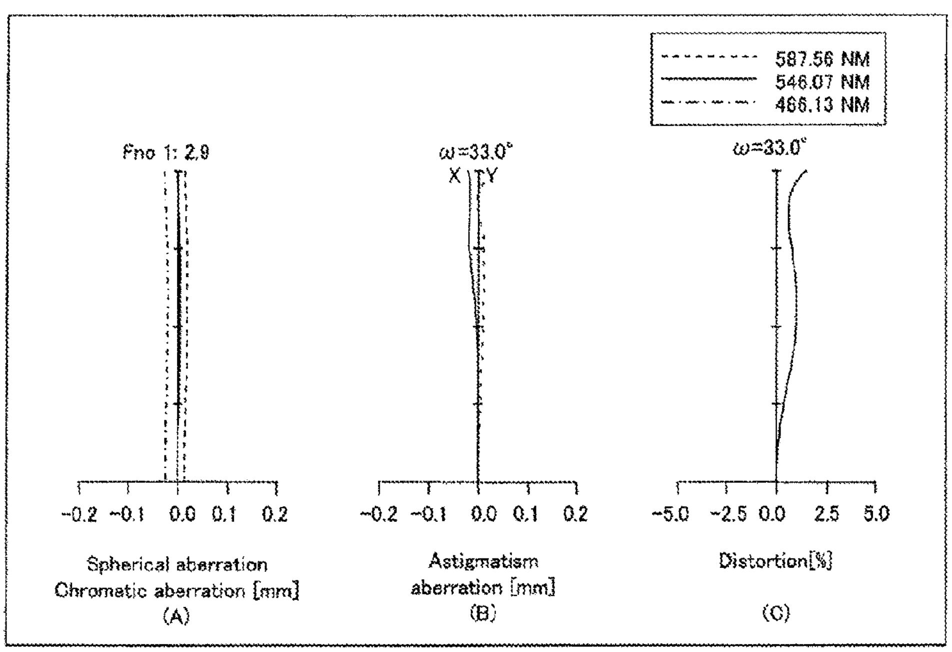

587.56 NM
546.07 NM
486.13 NM
Fno 1: 2.9
ω=33.0°
X Y
ω=33.0°
−0.2 −0.1 0.0 0.1 0.2
−0.2 −0.1 0.0 0.1 0.2
−5.0 −2.5 0.0 2.5 5.0
Spherical aberration
Chromatic aberration [mm]
(A)
Astigmatism
aberration [mm]
(B)
Distortion[%]
(C)

FIG. 15

DEFOCUS CHARACTERISTICS OF MTF OF EXAMPLE 4
1/4 SIZE : Fno#2.9 : f 3.61mm TT 4.0mm

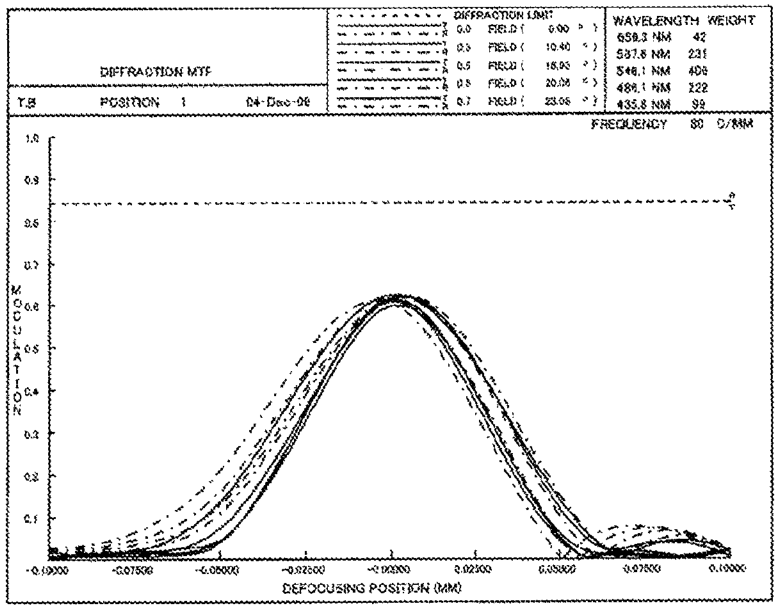


FIG. 16

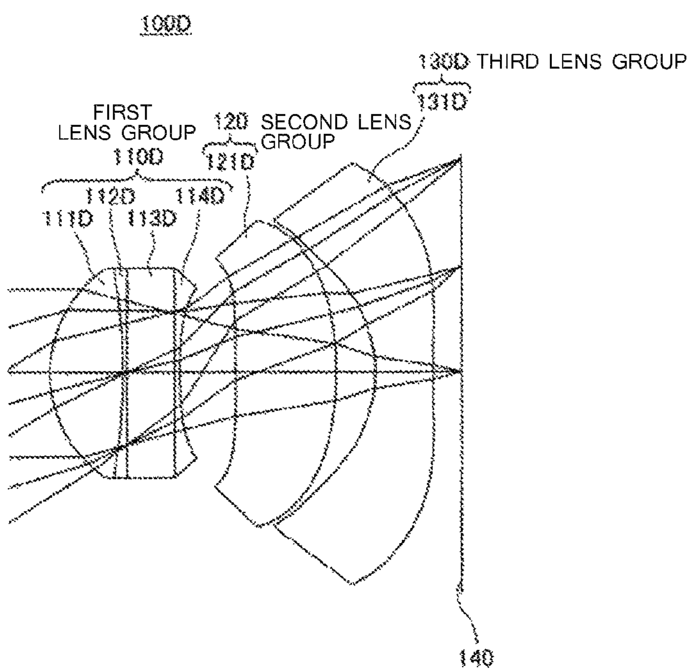


FIG. 17

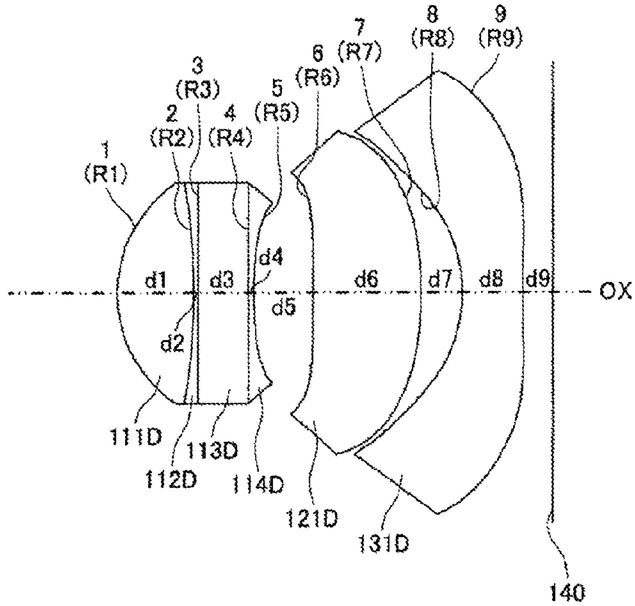

1
(R1)
2
(R2)
3
(R3)
4
(R4)
5
(R5)
6
(R6)
7
(R7)
8
(R8)
9
(R9)
d1
d2
d3
d4
d5
d6
d7
d8
d9
OX
111D
112D
113D
114D
121D
131D
140

FIG. 18

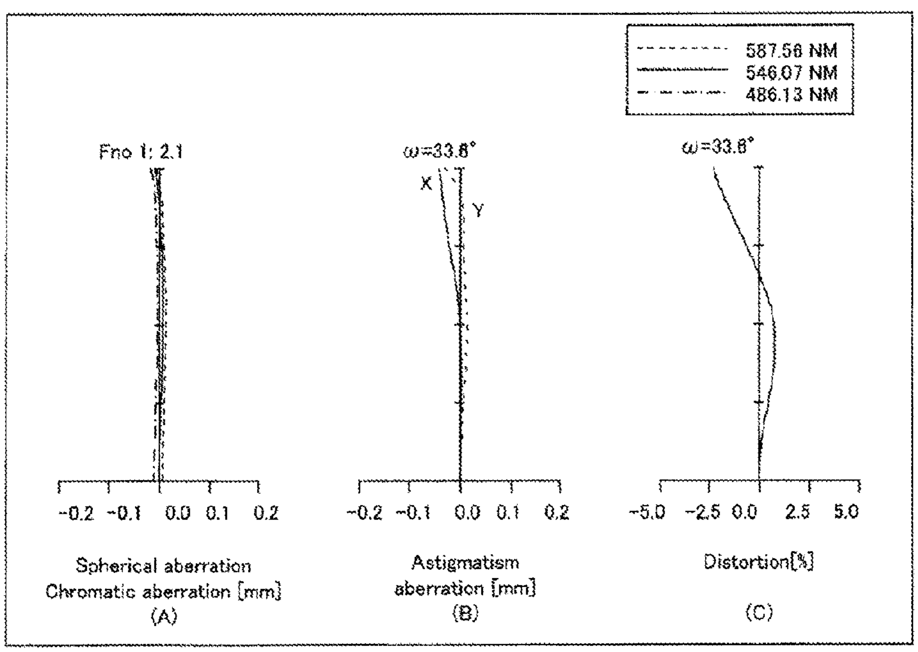
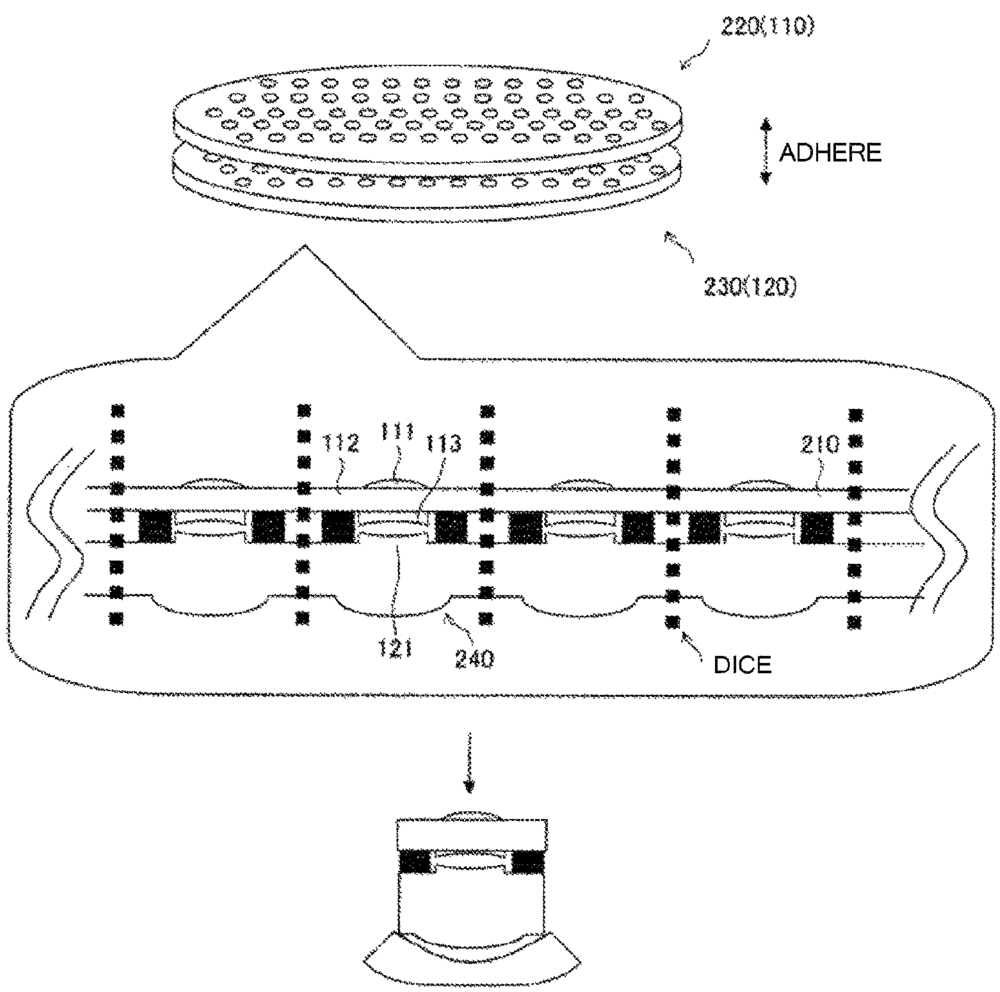
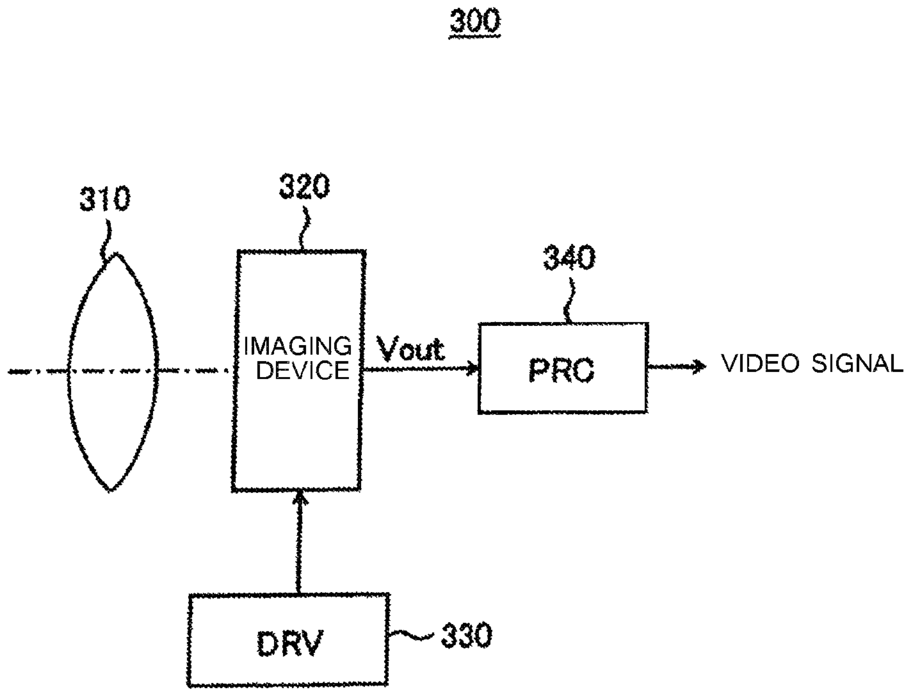

587.56 NM
546.07 NM
486.13 NM
Fno 1: 2.1
ω=33.8°
X
Y
ω=33.8°
-0.2 -0.1 0.0 0.1 0.2
-0.2 -0.1 0.0 0.1 0.2
-5.0 -2.5 0.0 2.5 5.0
Spherical aberration
Chromatic aberration [mm]
(A)
Astigmatism
aberration [mm]
(B)
Distortion[%]
(C)

FIG. 19



WITH REGARD TO THIRD GROUP, MOLDED LENSES OR INDIVIDUALLY CHANGED LENSES MANUFACTURED IN CASTING METHOD ARE ASSEMBLED INDIVIDUALLY.

FIG. 20



OPTICAL UNIT AND IMAGING APPARATUS

TECHNICAL FIELD

The present invention relates to an optical unit and an imaging apparatus, which are applied to imaging equipment.

BACKGROUND ART

High resolution, low cost, and downsizing are strongly demanded for imaging equipment mounted on recent years' mobile phone, personal computer (PC), and the like.

The cell pitch of an imaging element such as a CCD (Charge Coupled Device) or CMOS (Complementary Metal Oxide Semiconductor) image sensor has dramatically become narrow, and high image forming performance that suppresses optical aberrations, especially axial chromatic aberration more than a normal optical system, is required for an optical system.

Moreover, known is a technology for forming a lens in a wafer form to reduce costs for cost requirements.

A technology disclosed in Patent Document 1 is known as a representative example of them.

What is disclosed herein is called a hybrid (HYBRID) method.

In the hybrid method, multiple camera modules are simultaneously fabricated by forming multiple lenses on a wafer-shaped glass plate, and an imaging element wafer and the lens elements are adhered in a wafer form and are subsequently diced.

Moreover, for example, a technology disclosed in Patent Document 2 is known as a general imaging lens used for imaging equipment mounted on a mobile phone, a PC, or the like.

CITATION LIST

Patent Documents

Patent Document 1: US2006/0044450A1

Patent Document 2: Japanese Patent Application Laid-Open No. 2008-134411

Patent Document 3: Japanese Patent Application Laid-Open No. 2007-1219079

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

The advantages of the hybrid method are that an IR cut filter and a diaphragm can be formed on a glass wafer; accordingly, unlike before, these separate parts are unnecessary, and multiple finished products can be simultaneously made; accordingly, the number of assembly man-hours per product is small, and it is possible to reduce costs.

In the former case, there is also an advantage that a separate IR cut filter is unnecessary and accordingly the back focus of a lens can be short. Therefore, optical design having a high degree of freedom is possible.

With regard to CIF, VGA, and the like, the imaging area is small, and accordingly variations in the focal points of multiple lens elements formed in a wafer form do not become a big issue. Therefore, it is advantageous.

However, the disadvantage of the hybrid method is that the imaging area expands with increases in resolution to as high as 3M pixels or more, and accordingly variations in the focal points of the lens elements become large. As a result, if an imaging element and a lens element are adhered in a wafer form, the failure of defocus occurs frequently, and accordingly it becomes impossible to achieve the original purpose of manufacturing at low cost.

The advantage of the lens disclosed in Patent Document 2 is that high image forming performance is obtained by having a three-element configuration and using an aspheric surface heavily, and it is easy to adjust focus by placement in a screw barrel or the like since the lens projection shape is a circle.

However, there is a drawback that this lens needs an IR cut filter as a separate part and the number of parts is large since a diaphragm and the like are separate parts.

It is known that chromatic aberration is large and there is a limit to performance. Furthermore, small lens elements of a three-group configuration including the case here has a second lens that is largely bent, which results in drawbacks such as that it is not possible to evaporate AR coating accurately, and it is easy to become a factor of ghosting.

Moreover, including this case, a third lens deviates greatly from the spherical shape, and accordingly a limit to aberration correction is caused, and it is difficult to increase the brightness to less than Fno 2.4.

Moreover, for example, a technology disclosed in Patent Document 3 is known as a representative example of a four-group configuration.

The configuration is currently very widely adopted in a camera module having auto focus (AF); however, its depth of field is shallow and it is not suitable for a fixed-focus (FF) optical unit.

FIG. **1** is a view illustrating typical MTF characteristics of when a lens unit for ¼ size is designed with the current three-group/three-element lens.

FIG. **2** is a view illustrating typical MTF characteristics of when a lens unit for ¼ size is designed with the current four-group/four-element lens.

As shown here, the former has a low MTF at a peak. However, the focusing characteristics are very gentle, and the focus range where MTF becomes 0 is as wide as 100 μm.

On the other hand, the latter has a high MTF at a peak. However, the focusing characteristics are very steep, and the focus range where MTF becomes 0 is only 50 μm.

The former is optimal to an FF module, and the latter is optimal to an AF module.

The problem of the current optical system is that if three groups are changed to four groups to increase optical characteristics, the depth of field becomes shallow and therefore it becomes unsuitable for FF. Therefore, at the moment, there does not exist an optics solution optimal to an FF whose MTF is high, which is bright and whose depth of field is deep.

The present invention is to provide an optical unit and an imaging apparatus, which can realize a lens element that has a high MTF, is small, bright, and optimal to a fixed-focus camera while having an advantage of the three-group configuration that the depth of field is deep.

Solutions to Problems

An optical unit according to a first aspect of the present invention includes, arranged in order from an object side to an image plane side: a first lens group; a second lens group; and a third lens group, wherein the first lens group includes, arranged in order from the object side to the image plane side, a first lens element, a first transparent body, and a second lens element.

Preferably, the first lens element and the second lens element form a doublet lens.

An imaging apparatus according to a second aspect of the present invention includes: an imaging element; and an optical unit for forming an image of a subject in the imaging element, wherein the optical unit includes, arranged in order from an object side to an image plane side, a first lens group, a second lens group, and a third lens group, and the first lens group includes, arranged in order from an object side to an image plane side, a first lens element, a first transparent body, and a second lens element.

An imaging apparatus according to a third aspect of the present invention includes: an imaging element; and an optical unit for forming an image of a subject in the imaging element, wherein the optical unit includes, arranged in order from an object side to an image plane side, a first lens group, a second lens group, and a third lens group, the first lens group includes, arranged in order from an object side to an image plane side, a first lens element, a transparent body, and a second lens element, and the first lens element and the second lens element form a doublet lens.

Effects of the Invention

According to the present invention, it is possible to realize a lens element that has a high MTF, is small, bright, and optimal to a fixed-focus camera while having an advantage of the three-group configuration that the depth of field is deep.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a view illustrating typical MTF characteristics of when a lens unit for ¼ size is designed with a current three-group/three-element lens.

FIG. **2** is a view illustrating typical MTF characteristics of when a lens unit for ¼ size is designed with a current four-group/four-element lens.

FIG. **3** is a view illustrating a configuration example of an imaging lens according to a first embodiment of the present invention.

FIG. **4** is a view illustrating surface numbers assigned to lenses constituting lens groups, a substrate, and a cover glass constituting an imaging unit of the imaging lens according to the first embodiment.

FIG. **5** is an aberration diagram illustrating spherical aberration, astigmatism aberration, and distortion in Example 1.

FIG. **6** is a view illustrating the defocus characteristics of MTF from on-axis to 70% of an image height, viewed in 80 lps/mm of Example 1.

FIG. **7** is a view illustrating a configuration example of an imaging lens according to a second embodiment of the present invention.

FIG. **8** is a view illustrating surface numbers assigned to lenses constituting lens groups, substrates, and a cover glass constituting an imaging unit of the imaging lens according to the second embodiment.

FIG. **9** is an aberration diagram illustrating spherical aberration, astigmatism aberration, and distortion in Example 2.

FIG. **10** is a view illustrating a configuration example of an imaging lens according to a third embodiment of the present invention.

FIG. **11** is a view illustrating surface numbers assigned to lenses constituting lens groups, substrates, and a cover glass constituting an imaging unit of the imaging lens according to the third embodiment.

FIG. **12** is an aberration diagram illustrating spherical aberration, astigmatism aberration, and distortion in Example 3.

FIG. **13** is a view illustrating a configuration example of an imaging lens according to a fourth embodiment of the present invention.

FIG. **14** is an aberration diagram illustrating spherical aberration, astigmatism aberration, and distortion in Example 4.

FIG. **15** is a view illustrating the defocus characteristics of MTF from on-axis to 70% of an image height, viewed in 80 lps/mm of Example 4.

FIG. **16** is a view illustrating a configuration example of an imaging lens according to a fifth embodiment of the present invention.

FIG. **17** is a view illustrating surface numbers assigned to lenses constituting lens groups, a substrate, and a cover glass constituting an imaging unit of the imaging lens according to the fifth embodiment.

FIG. **18** is an aberration diagram illustrating spherical aberration, astigmatism aberration, and distortion in Example 5.

FIG. **19** is a view conceptually illustrating wafer-level optics according to a sixth embodiment of the present invention.

FIG. **20** is a block diagram illustrating a configuration example of an imaging apparatus in which the imaging lens according to the embodiment is adopted.

MODE FOR CARRYING OUT THE INVENTION

A description will hereinafter be given of embodiments of the present invention while associating them with accompanying drawings.

A description will be given in the following order:

1. First Embodiment (a first configuration example of an imaging lens adopting an optical unit),
2. Second Embodiment (a second configuration example of an imaging lens adopting an optical unit),
3. Third Embodiment (a third configuration example of an imaging lens adopting an optical unit),
4. Fourth Embodiment (a fourth configuration example of an imaging lens adopting an optical unit),
5. Fifth Embodiment (a fifth configuration example of an imaging lens adopting an optical unit),
6. Sixth Embodiment (a concept of wafer optics),
7. Seventh Embodiment (a configuration example of an imaging apparatus).

<1. First Embodiment>

FIG. **3** is a view illustrating a configuration example of an imaging lens that adopts an optical unit according to a first embodiment of the present invention.

An imaging lens **100** according to the first embodiment includes a first lens group **110**, a second lens group **120**, a third lens group **130** and an image plane **140**, which are arranged in order from an object side OBJS to the image plane side, as shown in FIG. **3**.

The imaging lens **100** is formed as a single focus lens. The first lens group **110**, the second lens group **120** and the third lens group **130** form an optical unit.

In the first embodiment, the first lens group **110** is formed by a conjugate including a plurality of lens elements arranged with a transparent body interposed therebetween.

The second lens group **120** is formed only of one third lens element.

The third lens group **130** is formed only of one fourth lens element.

Specifically, the first lens group **110** has replica lenses formed on and under a glass substrate.

The first lens group **110** is formed of a conjugate including a first lens element **111**, a first transparent body **112**, and a second lens element **113**, which are arranged in order from the object side OBJS to the image plane **130** side.

Here, the first lens element **111** has a plano-convex shape and a large Abbe number, a glass plate equivalent to BK7 manufactured by Schott is used for the transparent body (glass substrate) **112** for low cost manufacturing, and a plano-concave lens is formed for the second lens element **113**.

In the first embodiment, for example, the Abbe number of the first lens element **111** is set to 57.3, and the Abbe number of the second lens element **113** is set to 30.

Moreover, a diaphragm is realized by previously attaching a material having little transmission such as a chrome film to the object side of the glass substrate.

Similarly, an IR cut filter is also previously attached by vapor deposition onto the glass substrate.

From these, the chromatic aberration is corrected in the first lens group **110**, and it is also possible to have a structure that can easily remove the entire aberration.

The first lens group **110** as a whole has a strong positive power and greatly contributes to shortening of an optical length.

The second lens group **120** is formed only of a third lens element **121**.

Specifically, the second lens group **120** has characteristics of being formed by glass molding with, for example, an Abbe number of 31 and not being bent largely and therefore having a positive power.

This is because especially the first lens group **110** and the third lens group **130** greatly contribute to aberration correction, and accordingly it becomes unnecessary to bend the second lens group **120**.

Without large bending, it is possible to accurately perform AR coating, and ghosting and flare are unlikely to occur.

It is possible to use not only a plastic molded lens but also a glass molded lens and a high heat resistant lens of injection molding.

The third lens group **130** is formed only of a fourth lens element **141**.

Specifically, the third lens group **130** is constructed of a plastic molded lens made out of polycarbonate or a heat resistant resin, has a large negative power and a large incident surface, and is bent largely to the object side.

The center of curvature comes close to the diaphragm and therefore the astigmatism aberration and the coma aberration are corrected excellently.

Moreover, since the shape does not deviate greatly from the spherical shape, it is possible to realize a bright lens that has few changes in astigmatism aberration with respect to an incident NA due to an image height.

Moreover, an outgoing side surface has a shape that is also bent substantially to the object side, and orients a convex shape to the image side, which is a structure where ghosting is unlikely to occur.

Moreover, the incidence angle of light on an imager is suppressed low up until the perimeter and desirable performance can be obtained as the characteristics of a camera.

From these, a bright lens whose total optical length is short is realized.

In this manner, the first lens group **110** is formed of a conjugate of lens elements and a transparent body, and the second lens group **120** and the third lens group **130** are formed only of lens elements.

Therefore, the imaging lens **100** as a whole has lens surfaces including a first surface L**1**S**1**, a second surface L**1**S**2**, a third surface L**2**S**1**, a fourth surface L**2**S**2**, a fifth surface L**3**S**1**, and a sixth surface L**3**S**2**.

The first surface L**1**S**1** is formed of an object side surface of the first lens element **111**, and the second surface L**1**S**2** is formed of an image plane side surface of the second lens element **113**.

The third surface L**2**S**1** is formed of an object side surface of the third lens element **121**, and the fourth surface L**2**S**2** is formed of an image plane side surface of the third lens element **121**.

The fifth surface L**3**S**1** is formed of an object side surface of the fourth lens element **141**, and the sixth surface L**3**S**2** is formed of an image plane side surface of the fourth lens element **121**.

It is assumed that in the imaging lens **100** being a single focus lens, an imaging plane (image receiving surface) of a solid-state imaging device such as a CCD sensor or a CMOS sensor is arranged on the image plane **140**.

An unillustrated cover glass is arranged between the sixth surface L**3**S**2** and the image plane **140**. An optical member, in addition to a cover glass formed out of resin or glass, an infrared cut filter, a low-pass filter, and the like, may be arranged between the fourth surface SF**4** and the image plane **130**.

In the embodiment, in FIG. **1**, the left side is the object side (front) and the right side is the image plane side (rear).

The light flux entered from the object side forms an image on the image plane **140**.

A description will hereinafter be given of the configuration of an imaging lens of the embodiment and the operation thereof.

In the following description, the transparent body **112** may be expressed as a glass substrate, using the same reference sign.

The imaging lens **100** being a single focus lens in the embodiment is constructed to satisfy the following conditional expressions (1) to (11).

Conditional expression (1) is a relational expression related to the bending of the second lens group **120**.

[Math. 1]

$$-10 \le qL2 \le -0.4$$

$$qL2=(RL2S2+RL2S1)/(RL2S2-RL2S1) \tag{1}$$

where RL**2**S**1** represents the radius of curvature of an input side surface S**1** of the second lens group **120**, and RL**2**S**2** represents the radius of curvature of an outgoing side surface S**2** of the second lens group **120**.

In conditional expression (1), if the lower limit is exceeded, the negative power becomes weak, and the capability of aberration correction decreases, which is not suitable for a bright, small lens. Moreover, if the upper limit is exceeded, the lens becomes close to a biconvex lens, and an incidence angle of light becomes very large around the periphery of an incident surface of the second lens group **120** to cause extra astigmatism aberration and coma aberration, and the characteristics on the periphery of a screen deteriorates and therefore the merchantability is lost.

Conditional expression (2) is a relational expression related to an incident surface of the third lens group **130** (the paraxial quantity of the third lens group). In the embodiment, the third lens group **130** has characteristics of having a negative power, and having the radius of curvature of the incident surface in the vicinity of the diaphragm, which leads to high optical characteristics.

[Math. 2]

$$-3 \le RL3S1/f \le -0.2 \tag{2}$$

where RL3S1 represents the radius of curvature of an incident side surface S1 of the third lens group **130**, and f represents the focal length of the lens system.

In conditional expression (2), if the lower limit is exceeded, the radius of curvature does not come close to the diaphragm, and the capability of aberration correction decreases, which is not suitable for a bright, small lens. If the upper limit is exceeded, the curvature becomes too strong, and conversely aberration is corrected too much, which causes opposite aberration to deteriorate the optical characteristics.

Conditional expression (3) relates to a focal length fg**1** of the first lens group **110**.

[Math. 3]

$$0.5 \le fg1/f \le 1.5 \tag{3}$$

In conditional expression (3), if the lower limit is exceeded, the positive power of the first group becomes too strong and the manufacturing tolerance decreases and therefore it is not suitable for the applications of the present invention that aims for an inexpensive module. If the upper limit is exceeded, the positive power becomes weak and the lens becomes close to a retrofocus optical system. Then, the optical length extends, which is not suitable for the applications of the present invention having the object of a small module.

Conditional expression (4) relates to a focal length fg**2** of the second lens group **120**.

[Math. 4]

$$0.5 \le fg2/f \le 50 \tag{4}$$

In conditional expression (4), if the lower limit is exceeded, the positive power becomes too strong and the manufacturing tolerance decreases, which is not suitable for the applications of the present invention that aims for an inexpensive module. If the upper limit is exceeded, the power becomes weak and the capability of aberration correction decreases, which is not suitable for a bright, small lens.

Conditional expression (5) relates to a focal length fg**3** of the third lens **130** group.

[Math. 5]

$$-5 \le fg3/f \le -0.3 \tag{5}$$

In conditional expression (5), if the lower limit is exceeded, the power becomes weak and the capability of aberration correction decreases, which is not suitable for a bright, small lens. If the upper limit is exceeded, the power becomes too strong, and conversely aberration is corrected too much, which causes opposite aberration to deteriorate the optical characteristics.

Conditional expression (6) relates to the angle of view.

[Math. 6]

$$20 \le \omega \le 40 \tag{6}$$

where ω represents a half angle of view.

In conditional expression (6), if the lower limit is exceeded, the angle of view becomes too narrow and the lens becomes similar to a telephoto lens, which is not suitable for a cellular application and a camera for a personal computer (PC), which often image the vicinity. If the upper limit is exceeded, the lens becomes a high-angle lens too much, and is not suitable for a cellular application and a PC camera that often takes a self-portrait.

Conditional expression (7) relates to an Abbe number νE1 of the first lens element **111**.

[Math. 7]

$$45 \le \nu E1 \le 90 \tag{7}$$

In conditional expression (7), if the lower limit is exceeded, the chromatic aberration becomes large, which is not suitable for high resolution. If the upper limit is exceeded, lens glass material becomes unpractical.

Conditional expression (8) relates to an Abbe number νE2 of the second lens element **113**.

[Math. 8]

$$20 \le \nu E2 \le 60 \tag{8}$$

In conditional expression (8), if the lower limit is exceeded, lens glass material becomes unpractical. If the upper limit is exceeded, the chromatic aberration becomes large, which is not suitable for high resolution.

Conditional expression (9) relates to an F-number Fno.

[Math. 9]

$$1.0 \le Fno \le 3.0 \tag{9}$$

In conditional expression (9), if the lower limit is exceeded, vignetting occurs in the imager when light enters the imager, which causes problems such as color mixture and the performance of a camera deteriorates. If the upper limit is exceeded, the lens becomes dark, and it is contrary to the object of the embodiment of the present invention.

Conditional expression (10) relates to an optical length TT of the lens system.

[Math. 10]

$$0.8 \le TT/f \le 1.5 \tag{10}$$

In conditional expression (10), if the lower limit is exceeded, the lens becomes very compact and desirable; however, the shape of the lens becomes difficult to manufacture, which is not desirable. If the upper limit is exceeded, the module itself upsizes and it is contrary to the object of the embodiment of the present invention.

Conditional expression (11) relates to back focus BF of the lens system.

[Math. 11]

$$0.01 \le BF \le 0.6 \tag{11}$$

In conditional expression (11), if the lower limit is exceeded, it becomes impossible to make adjustments when manufacturing, which is a problem. Exceeding the upper limit brings a constraint to lens design, which makes no sense.

However, this does not apply if some part is inserted between the lens system and the imaging element.

The above conditional expressions (1) to (11) are common to Examples 1 to 5 that will be handled below, and their appropriate adoption as necessary realizes more preferable imaging performance and a compact optical system, which are suitable for individual imaging elements or imaging apparatuses.

When a direction from the object side to the image plane side is positive, k is a conic coefficient, A, B, C and D are aspheric coefficients, and r is the radius of the center of curvature, the shape of the aspheric surface of a lens is expressed in the following expression. y represents the height of light from the optical axis, and c represents the inverse (1/r) of the radius of the center of curvature r, respectively.

However, X represents the distance from a tangent plane with respect to the vertex of an aspheric surface, A a fourth order aspheric coefficient, B a sixth order aspheric coefficient, Can eighth order aspheric coefficient, D a tenth order aspheric coefficient, respectively.

Aspheric Surface Equation

$$X = \frac{cy^2}{1+\sqrt{1-(1+k)c^2y^2}} + Ay^4 + By^6 + Cy^8 + Dy^{10} \qquad \text{[Math. 1]}$$

FIG. 4 is a view illustrating surface numbers assigned to lenses constituting lens groups, a substrate, and a cover glass constituting an imaging unit of the imaging lens according to the first embodiment.

Specifically, a surface number of number one is assigned to an object side surface (convex surface) of the first lens element 111, and a surface number of number two to a boundary surface (joint surface) between an image plane side surface of the first lens element 111 and an object side surface of the transparent body.

A surface number of number three is assigned to a boundary surface (joint surface) between an image plane side surface of the transparent body 112 and an object side surface of the second lens element 113.

A surface number of number four is assigned to an image plane side surface of the second lens element 113.

A surface number of number five is assigned to an object side surface of the third lens element 121, and a surface number of number six to an image plane side surface of the third lens element 121.

A surface number of number seven is assigned to an object side surface of the fourth lens element 131, and a surface number of number eight to an image plane side surface of the fourth lens element 131.

Moreover, as shown in FIG. 4, in the imaging lens 100 of the embodiment, the radius of the center of curvature of the object side surface (number one) 1 of the first lens element 111 is set as R1.

The radius of the center of curvature of the boundary surface (joint surface) 2 between the image plane side surface of the first lens element 111 and the object side surface of the transparent body 112 is set as R2.

The radius of the center of curvature of the boundary surface (joint surface) 3 between the image plane side surface of the transparent body 112 and the object side surface of the second lens element 113 is set as R3.

The radius of the center of curvature of the image plane side surface 4 of the second lens element 113 is set as R4.

The radius of the center of curvature of the object side surface 5 of the third lens element 121 is set as R5, and the radius of the center of curvature of the image plane side surface 6 of the third lens element 121 as R6.

The radius of the center of curvature of the object side surface 7 of the fourth lens element 131 is set as R7, and the radius of the center of curvature of the image plane side surface 8 of the fourth lens element 131 as R8.

The radii of the center of curvature R2 and R3 of the surfaces 2 and 3 are infinite (INFINITY).

Moreover, as shown in FIG. 4, the distance on an optical axis OX between the surfaces 1 and 2, the distance being the thickness of the first lens element 111, is set as d1, and the distance on the optical axis OX between the surfaces 2 and 3, the distance being the thickness of the transparent body 112, is set as d2.

The distance on the optical axis OX between the surfaces 3 and 4, the distance being the thickness of the second lens element 113, is set as d3, and the distance on the optical axis OX between the image plane side surface 4 of the second lens element 113 and the object side surface 5 of the third lens element 121 is set as d4.

The distance on the optical axis OX between the surfaces 5 and 6, the distance being the thickness of the third lens element 121, is set as d5, and the distance on the optical axis OX between the image plane side surface 6 of the third lens element 121 and the image plane side surface 7 of the fourth lens element 131 is set as d6.

The distance on the optical axis OX between the surfaces 7 and 8, the distance being the thickness of the fourth lens element 131, is set as d7, and the distance between the image plane side surface 8 of the fourth lens element 131 and the image plane 140 is set as d8.

Example 1 will be shown below with specific numerical values of the imaging lens. In Example 1, the surface numbers shown in FIG. 4 are assigned to the lens elements glass substrate (transparent body) and the imaging plane 130 constituting an imaging unit of the imaging lens 100.

EXAMPLE 1

Tables 1, 2, 3 and 4 show numerical values of Example 1. The numerical values of Example 1 correspond to the imaging lens 100 of FIG. 1.

Example 1 is a design example for a 5-megapixel (Mage pixel) CMOS imager of ¼ size and 1.4 μm pitch.

Table 1 shows the radii of curvature (R: mm), distances (d: mm), refractive indices (nd), and variances (νd) of the lens elements, the glass substrate (transparent body), and the like, which correspond to the surface numbers of the imaging lens in Example 1.

TABLE 1

Example 1 Lens Configuration Data

Surface Number	R	d	nd	νd
1:	1.385	0.700	1.51	57.3
2:	INFINITY	0.500	1.52	55.0
3:	INFINITY	0.050	1.60	30.0
4:	4.145	0.698		
5:	47.391	1.136	1.69	31.3
6:	−2.459	0.387		
7:	−1.121	0.600	1.59	30.0
8:	−18.762	0.300		

Table 2 shows the fourth, sixth, eighth and tenth order aspheric coefficients of the surface 1 of the first lens element 111 that includes an aspheric surface in Example 1, the surface 4 of the second lens element 113, the surface 5 of the third lens element 121, and the surface 6 of the third lens element 121.

Furthermore, shown are the fourth, sixth, eighth and tenth order aspheric coefficients of the surface 7 of the fourth lens element 131, and the surface 6 of the fourth lens element 131.

In Table 2, K represents a conic constant, A a fourth order aspheric coefficient, B a sixth order aspheric coefficient, C an eighth order aspheric coefficient, and D a tenth order aspheric coefficient, respectively.

TABLE 2

Example 1 Aspheric Data

First Surface:	K: 0.299	A: −0.186E−01	B: −0.414E−02	C: −0.327E−02	D: −0.695E−02
Fourth Surface:	K: 4.400	A: 0.485E−01	B: 0.543E−01	C: −0.724E−01	D: 0.125E+00

TABLE 2-continued

Example 1 Aspheric Data					
Fifth Surface:	K: 10.000	A: 0.154E−01	B: −0.179E−01	C: 0.541E−02	D: −0.177E−02
Sixth surface:	K: −0.369	A: 0.154E−01	B: −0.179E−01	C: 0.541E−02	D: −0.177E−02
Seventh Surface:	K: −1.043	A: 0.677E−01	B: −0.718E−01	C: 0.385E−01	D: −0.726E−02
Eighth Surface:	K: 10.000	A: 0.140E−01	B: −0.228E−01	C: 0.591E−02	D: −0.567E−03

Table 3 specifically shows the focal length f, numerical aperture F, half angle of view ω, and lens length H of the imaging lens **100** in Example 1.

Here, the focal length f is set to 3.64 [mm], the numerical aperture F to 2.1, the half angle of view ω to 31.5 deg, and the lens length H to 4.37 [mm].

TABLE 3

Example 1 Configuration Data
f (Focal Length) = 3.64 mm
F (Numerical Aperture) = 2.1
ω (Half Angle of View) = 31.5 deg
H (Total Lens Length) = 4.37 mm

Table 4 shows that the above conditional expressions (1) to (11) are satisfied in Example 1.

TABLE 4

Values of Conditional Expressions by Example

Conditional Expression	Example 1
(1)	−0.90
(2)	−0.31
(3)	1.02
(4)	0.93
(5)	−0.56
(6)	31.5
(7)	57.3
(8)	30
(9)	2.1
(10)	1.20
(11)	0.3

As shown in Table 4, in Example 1, a bending factor qL**2** of the second lens group **120** is set to −0.9, and the condition defined in conditional expression (1) is satisfied.

The incident surface of the third lens **130** group (the paraxial quantity of the third lens group) RL**3S1**/f is set to −0.31, and the condition defined in conditional expression (2) is satisfied.

The focal length fg**1** of the first lens group **110** is set to 1.02, and the condition defined in conditional expression (3) is satisfied.

The combined focal length fg**2** of the second lens group **120** is set to 0.93, and the condition defined in conditional expression (4) is satisfied.

The combined focal length fg**3** of the fourth lens group **130** is set to −0.56, and the condition defined in conditional expression (5) is satisfied.

The half angle of view ω is set to 31.5, and the condition defined in conditional expression (6) is satisfied.

The Abbe number νE1 of the first lens element **111** is set to 57.3, and the condition defined in conditional expression (7) is satisfied.

The Abbe number νE2 of the second lens element **113** is set to 30, and the condition defined in conditional expression (8) is satisfied.

The F-number Fno of the lens system is set to 2.1, and the condition defined in conditional expression (9) is satisfied.

The optical length TT of the lens system is set to 1.20, and the condition defined in conditional expression (10) is satisfied.

The back focus length FB of the lens system is set to 0.3, and the condition defined in conditional expression (11) is satisfied.

FIG. **5** is an aberration diagram illustrating spherical aberration (chromatic aberration), astigmatism aberration, and distortion in Example 1. (A) in FIG. **5** represents the spherical aberration (chromatic aberration), (B) in FIG. **5** the astigmatism aberration, and (C) in FIG. **5** the distortion, respectively.

As can be seen from FIG. **5**, according to Example 1, the aberrations of a spherical surface, astigmatism and distortion are corrected excellently, and an imaging lens including an optical unit that is excellent in image forming performance can be obtained.

FIG. **6** is a view illustrating the defocus characteristics of MTF from on-axis to 70% of an image height, viewed in 80 lps/mm of Example 1.

Moreover, as described above, FIG. **1** similarly illustrates the defocus characteristics of MTF from on-axis to 70% of an image height, viewed in 80 lps/mm of the current three-group/three-element design. FIG. **2** similarly illustrates the defocus characteristics of MTF from on-axis to 70% of an image height, viewed in 80 lps/mm of the current four-group/four-element design. These are designed on conditions similar to those of Example 1.

When they are seen from the range of defocus where MTF becomes 0, Example 1 is 80 μm, the three-group/three-element and Fno 2.9 is 100 μm, and the four-group/four-element and Fno 2.9 is 80 μm.

The depth of field is normally inversely proportional to Fno if the focal length is the same.

For example, the four-group/four-element and Fno 2.9 has a depth of field of 80 μm×2.1/2.9=58 μm given that Fno is set to 2.1.

However, in this example, even if Fno is 2.1, a depth of field of 80 μm is ensured, and also a high MTF is maintained, and therefore, it can be seen that it is a bright lens being more suitable for practical use.

<2. Second Embodiment>

FIG. **7** is a view illustrating a configuration example of an imaging lens according to a second embodiment of the present invention.

In an imaging lens **100A** according to the second embodiment shown in FIG. **7**, a second lens group **120A** is formed of a conjugate of a third lens element **121A**, a second transparent body **122**, and a fourth lens element **123**, similarly to the first lens group.

A third lens group **130**A is formed of a fifth lens element **132**.

In the imaging lens **100**A, each lens group is constructed as follows.

A first lens group **100**A has a first lens element **111** of a plano-convex shape and, for example, an Abbe number of 53.1, which is adhered to an object side of a glass plate equivalent to BK7, and a second lens element **113** of an Abbe number of 30 and a plano-concave shape, which is adhered to the opposite side.

Here, a diaphragm is realized by previously attaching a material having little transmission such as a chrome film to the object side of the glass substrate.

Similarly, an IR cut filter is also previously attached by vapor deposition onto the glass substrate.

From these, the chromatic aberration is corrected in the first lens group **110**A, and it is also possible to have a structure that can easily remove the entire aberration. The first lens group **110**A as a whole has a strong positive power and greatly contributes to shortening of an optical length.

The second lens group **120**A is formed of a lens in the hybrid (HYBRID) method using a glass substrate, and the third lens elements **121**A of, for example, an Abbe number of 30 are adhered to the front and back of the glass substrate equivalent to BK7.

The characteristics are not being bent largely and having a positive power.

This is because especially the first lens group **110**A and the third lens group **130**A greatly contribute to aberration correction, and accordingly it becomes unnecessary to bend the second lens group **120**A.

Without large bending, it is possible to accurately perform AR coating, and ghosting and flare are unlikely to occur.

Moreover, the thickness of the lens can be made thin, which facilitates manufacture and therefore it becomes an advantage.

The third lens group **130**A is constructed of a plastic molded lens made out of polycarbonate or a heat resistant resin, and has a large negative power and a large incident surface, and is bent to the object side.

The center of curvature comes close to the diaphragm and therefore the astigmatism aberration and the coma aberration are corrected excellently.

Moreover, since the shape does not deviate greatly from the spherical shape, it is possible to realize a bright lens that has few changes in astigmatism aberration with respect to an incident NA due to an image height.

Moreover, an outgoing side surface has a shape that is also bent substantially to the object side, and orients a convex shape to the image side, which is a structure where ghosting is unlikely to occur. Moreover, the incidence angle of light on an imager is suppressed low up until the perimeter and desirable performance can be obtained as the characteristics of a camera.

From these, the second embodiment can realize a bright lens having a short total optical length and being suitable for practical use, similarly to the first embodiment.

FIG. **8** is a view illustrating surface numbers assigned to lenses constituting lens groups, substrates, and a cover glass constituting an imaging unit of the imaging lens according to the second embodiment.

Specifically, a surface number of number one is assigned to an object side surface (convex surface) of the first lens element **111**, and a surface number of number two to a boundary surface (joint surface) between an image plane side surface of the first lens element **111** and an object side surface of the transparent body.

A surface number of number three is assigned to a boundary surface (joint surface) between an image plane side surface of the transparent body **112** and an object side surface of the second lens element **113**.

A surface number of number four is assigned to an image plane side surface of the second lens element **113**.

A surface number of number five is assigned to an object side surface of the third lens element **121**A, and a surface number of number six to a boundary surface (joint surface) between an image plane side surface of the third lens element **121**A and an object side surface of the second transparent body **122**.

A surface number of number seven is assigned to a boundary surface (joint surface) between an image plane side surface of the second transparent body **122** and an object side surface of the fourth lens element **123**.

A surface number of number eight is assigned to an image plane side surface of the fourth lens element **123**.

A surface number of number nine is assigned to an object side surface of the fifth lens element **132**, and a surface number of number ten to an image plane side surface of the fifth lens element **132**.

Moreover, as shown in FIG. **8**, in the imaging lens **100**A of the embodiment, the radius of the center of curvature of the object side surface (number one) **1** of the first lens element **111** is set as R**1**.

The radius of the center of curvature of the boundary surface (joint surface) **2** between the image plane side surface of the first lens element **111** and the object side surface of the transparent body **112** is set as R**2**.

The radius of the center of curvature of the boundary surface (joint surface) **3** between the image plane side surface of the transparent body **112** and the object side surface of the second lens element **113** is set as R**3**.

The radius of the center of curvature of the image plane side surface **4** of the second lens element **113** is set as R**4**.

The radius of the center of curvature of the object side surface (number five) **1** of the third lens element **121**A is set as R**5**.

The radius of the center of curvature of the boundary surface (joint surface) **6** between the image plane side surface of the third lens element **121**A and the object side surface of the second transparent body **122** is set as R**6**.

The radius of the center of curvature of the boundary surface (joint surface) **7** between the image plane side surface of the second transparent body **122** and the object side surface of the fourth lens element **123** is set as R**7**.

The radius of the center of curvature of the image plane side surface **8** of the fourth lens element **123** is set as R**8**.

The radius of the center of curvature of the object side surface **9** of the fifth lens element **132** is set as R**9**, and the radius of the center of curvature of the image plane side surface **10** of the fifth lens element **132** as R**10**.

The radii of the center of curvature R**2**, R**3**, R**6**, and R**7** of the surfaces **2**, **3**, **6** and **7** are infinite (INFINITY).

Moreover, as shown in FIG. **8**, the distance on an optical axis OX between the surfaces **1** and **2**, the distance being the thickness of the first lens element **111**, is set as d**1**, and the distance on the optical axis OX between the surfaces **2** and **3**, the distance being the thickness of the transparent body **112**, is set as d**2**.

The distance on the optical axis OX between the surfaces **3** and **4**, the distance being the thickness of the second lens element **113**, is set as d**3**, and the distance on the optical axis OX between the image plane side surface **4** of the second lens element **113** and the object side surface **5** of the third lens element **121**A is set as d**4**.

The distance on the optical axis OX between the surfaces **5** and **6**, the distance being the thickness of the third lens element **121**A, is set as d**5**, and the distance on the optical axis OX between the surfaces **6** and **7**, the distance being the thickness of the second transparent body **122**, is set as d**6**.

The distance on the optical axis OX between the surfaces **7** and **8**, the distance being the thickness of the fourth lens element **123**, is set as d**7**, and the distance on the optical axis OX between the image plane side surface **8** of the fourth lens element **123** and the object side surface **9** of the fifth lens element **132** is set as d**8**.

The distance on the optical axis OX between the surfaces **9** and **10**, the distance being the thickness of the fifth lens element **132**, is set as d**9**, and the distance between the image plane side surface **10** of the fifth lens element **132** and the image plane **140** is set as d**10**.

Table 6 shows the fourth, sixth, eighth and tenth order aspheric coefficients of the surface **1** of the first lens element **111** that includes an aspheric surface in Example 2, the surface **4** of the second lens element **113**, the surface **5** of the third lens element **121**A, and the surface **8** of the fourth lens element **123**.

Furthermore, shown are the fourth, sixth, eighth and tenth order aspheric coefficients of the surface **9** of the fifth lens element **132**, and the surface **10** of the fifth lens element **132**.

In Table 6, K represents a conic constant, A a fourth order aspheric coefficient, B a sixth order aspheric coefficient, C an eighth order aspheric coefficient, and D a tenth order aspheric coefficient, respectively.

TABLE 6

Example 2 Aspheric Data					
First Surface:	K−0.551	A: 0.179E−01	B: 0.315E−01	C: −0.251E−01	D: 0.194E−01
Fourth Surface:	K: 10.000	A: 0.289E−01	B: 0.762E−01	C: −0.143E+00	D: 0.174E+00
Fifth Surface:	K: 10.000	A: −0.248E−01	B: −0.260E−01	C: 0.121E−01	D: −0.184E−01
Eighth Surface:	K: −4.839	A: 0.156E−01	B: −0.513E−01	C: 0.277E−01	D: −0.536E−02
Ninth Surface:	K: −3.163	A: −.457E−01	B: −0.812E−01	C: 0.684E−01	D: −0.137E−01
Tenth Surface:	K: −10.000	A: 0.434E−01	B: −0.464E−01	C: 0.123E−01	D: −0.116E−02

Example 2 will be shown below with specific numerical values of the imaging lens. In Example 2, the surface numbers shown in FIG. **8** are assigned to the lens elements glass substrates (transparent bodies) and the imaging plane **140** constituting an imaging unit of the imaging lens **100**A.

EXAMPLE 2

Tables 5, 6, 7 and 8 show numerical values of Example 2. The numerical values of Example 2 correspond to the imaging lens **100**A of FIG. **7**.

Example 2 is a design example for a 5-megapixel (Mage pixel) CMOS imager of ¼ size and 1.4 μm pitch.

Table 5 shows the radii of curvature (R: mm), distances (d: mm), refractive indices (nd), and variances (νd) of the lens elements, the glass substrates (transparent bodies), and the like, which correspond to the surface numbers of the imaging lens in Example 2.

TABLE 5

Example 2 Configuration Data

Surface Number	R	d	nd	νd
1:	1.374	0.600	1.51	53.1
2:	INFINITY	0.500	1.52	64.2
3:	INFINITY	0.110	1.60	30.0
4:	3.902	0.649		
5:	14.528	0.156	1.60	30.0
6:	INFINITY	0.418	1.52	64.2
7:	INFINITY	0.500	1.60	30.0
8:	−2.868	0.435		
9:	−1.251	0.700	1.59	30.0
10:	−15.033	0.250		

Table 7 specifically shows the focal length f, numerical aperture F, half angle of view ω, and lens length H of the imaging lens **100** in Example 2.

Here, the focal length f is set to 3.65 [mm], the numerical aperture F to 2.1, the half angle of view ω to 31.6 deg, and the lens length H to 4.32 [mm].

TABLE 7

Example 2 Configuration Data
f (Focal Length) = 3.65 mm
F (Numerical Aperture) = 2.1
ω (Half Angle of View) = 31.6 deg
H (Total Lens Length) = 4.32 mm

Table 8 shows that the above conditional expressions (1) to (11) are satisfied in Example 2.

TABLE 8

Values of Conditional Expressions by Example

Conditional Expression	Example 2
(1)	−0.67
(2)	−0.34
(3)	1.04
(4)	1.12
(5)	−0.65
(6)	31.6
(7)	53.1
(8)	30
(9)	2.1
(10)	1.18
(11)	0.25

As shown in Table 8, in Example 2, the bending factor qL**2** of the second lens group **120** is set to −0.67, and the condition defined in conditional expression (1) is satisfied.

The incident surface of the third lens **130** group (the paraxial quantity of the third lens group) RL**3S1**/f is set to −0.34, and the condition defined in conditional expression (2) is satisfied.

The focal length fg**1** of the first lens group **110** is set to 1.04, and the condition defined in conditional expression (3) is satisfied.

The combined focal length fg**2** of the second lens group **120** is set to 1.12, and the condition defined in conditional expression (4) is satisfied.

The combined focal length fg**3** of the fourth lens group **130** is set to −0.65, and the condition defined in conditional expression (5) is satisfied.

The half angle of view ω is set to 31.6, and the condition defined in conditional expression (6) is satisfied.

The Abbe number νE1 of the first lens element **111** is set to 53.1, and the condition defined in conditional expression (7) is satisfied.

The Abbe number νE2 of the second lens element **113** is set to 30, and the condition defined in conditional expression (8) is satisfied.

The F-number Fno of the lens system is set to 2.1, and the condition defined in conditional expression (9) is satisfied.

The optical length TT of the lens system is set to 1.18, and the condition defined in conditional expression (10) is satisfied.

The back focus length FB of the lens system is set to 0.25, and the condition defined in conditional expression (11) is satisfied.

FIG. **9** is an aberration diagram illustrating spherical aberration (chromatic aberration), astigmatism aberration, and distortion in Example 2. (A) in FIG. **9** represents the spherical aberration (chromatic aberration), (B) in FIG. **9** the astigmatism aberration, and (C) in FIG. **9** the distortion, respectively.

As can be seen from FIG. **9**, according to Example 2, the aberrations of a spherical surface, astigmatism and distortion are corrected excellently, and an imaging lens including an optical unit that is excellent in image forming performance can be obtained.

<3. Third Embodiment>

FIG. **10** is a view illustrating a configuration example of an imaging lens according to a third embodiment of the present invention.

In an imaging lens **100**B according to the third embodiment shown in FIG. **10**, a second lens group **120**A is formed of a conjugate of a third lens element **121**B, a second transparent body **122**B, and a fourth lens element **123**B, similarly to the first lens group.

Similarly, a third lens group **130**B is formed of a conjugate of a fifth lens element **133**, a third transparent body **134**, and a sixth lens element **135**, similarly to the first and second lens groups.

In the imaging lens **100**B, each lens group is constructed as follows.

A first lens group **110**B has a first lens element **111** of a plano-convex shape and, for example, an Abbe number of 53.1, which is adhered to an object side of a glass plate equivalent to BK7, and a second lens element **113** of an Abbe number of 30 and a plano-concave shape, which is adhered to the opposite side.

Here, a diaphragm is realized by previously attaching a material having little transmission such as a chrome film to the object side of the glass substrate.

Similarly, an IR cut filter is also previously attached by vapor deposition onto the glass substrate.

From these, the chromatic aberration is corrected in the first lens group **110**, and it is also possible to have a structure that can easily remove the entire aberration.

The first lens group **110**B as a whole has a strong positive power and greatly contributes to shortening of an optical length.

The second lens group **120**B is formed of a lens in the hybrid (HYBRID) method using a glass substrate, and lens elements of, for example, an Abbe number of 30 are adhered to the front and back of the glass substrate equivalent to BK7.

The characteristics are not being bent largely and having a positive power.

This is because especially the first lens group **110** and the third lens group **130**B greatly contribute to aberration correction, and accordingly it becomes unnecessary to bend the second lens group **120**B.

Without large bending, it is possible to accurately perform AR coating, and ghosting and flare are unlikely to Occur.

Moreover, the thickness of the lens can be made thin, which facilitates manufacture and therefore it becomes an advantage.

The third lens group **130**B is also formed of a lens in the hybrid (HYBRID) method, and the fifth lens element **133** of a substantially plano-concave shape and, for example, an Abbe number of 30.0 is adhered to an object side of the glass substrate equivalent to BK7. In the third lens group **130**B, the sixth lens element **135** of an Abbe number of 30 and a substantially plano-convex shape is adhered to the opposite side.

The third lens group **130**B has a large negative power and a large incident surface, and is bent to the object side.

The center of curvature comes close to the diaphragm and therefore the astigmatism aberration and the coma aberration are corrected excellently.

Moreover, since the shape does not deviate greatly from the spherical shape, it is possible to realize a bright lens that has few changes in astigmatism aberration with respect to an incident NA due to an image height.

Moreover, an outgoing side surface has a shape that is also bent substantially to the object side, and orients a convex shape to the image side, which is a structure where ghosting is unlikely to occur.

Moreover, the incidence angle of light on an imager is suppressed low up until the perimeter and desirable performance can be obtained as the characteristics of a camera.

From these, a bright lens having a short total optical length and being suitable for practical use can be realized, similarly to the first and second embodiments.

In this manner, if all the three groups are constructed in the hybrid (HYBRID) method, and they are joined in a wafer form, they are difficult to cut off.

Since the yield depends on the size of the third lens group, a space between the first lens group and the second lens group increases and accordingly it is not efficient.

Moreover, the third lens group has a lens much thicker than a wafer thickness, and a problem of manufacture that the wafer suffers some warping arises, and there is a problem that it is difficult to have an accurate profile system.

Therefore, the first- and second-embodiment types are desirable. However, all the three groups may be fabricated in the hybrid (HYBRID) method, only first and second lens groups may be bonded in a wafer form to be diced, and the dice may be bonded to the dice of the third group individually.

FIG. **11** is a view illustrating surface numbers assigned to lenses constituting lens groups, substrates, and a cover glass constituting an imaging unit of the imaging lens according to the third embodiment.

Specifically, a surface number of number one is assigned to an object side surface (convex surface) of the first lens element **111**, and a surface number of number two to a boundary surface (joint surface) between an image plane side surface of the first lens element **111** and an object side surface of the transparent body.

A surface number of number three is assigned to a boundary surface (joint surface) between an image plane side surface of the transparent body **112** and an object side surface of the second lens element **113**.

A surface number of number four is assigned to an image plane side surface of the second lens element **113**.

A surface number of number five is assigned to an object side surface of the third lens element **121**B, and a surface number of number six to a boundary surface (joint surface) between an image plane side surface of the third lens element **121**B and an object side surface of the second transparent body **122**B.

A surface number of number seven is assigned to a boundary surface (joint surface) between an image plane side surface of the second transparent body **122**B and an object side surface of the fourth lens element **123**B.

A surface number of number eight is assigned to an image plane side surface of the fourth lens element **123**B.

A surface number of number nine is assigned to an object side surface of the fifth lens element **133**, and a surface number of number ten to a boundary surface (joint surface) between an image plane side surface of the fifth lens element **133** and an object side surface of the third transparent body **134**.

A surface number of number eleven is assigned to a boundary surface (joint surface) between an image plane side surface of the third transparent body **134** and an object side surface of the sixth lens element **145**.

A surface number of number twelve is assigned to an image plane side surface of the sixth lens element **135**.

Moreover, as shown in FIG. **11**, in the imaging lens **100**B of the embodiment, the radius of the center of curvature of the object side surface (number one) **1** of the first lens element **111** is set as R**1**.

The radius of the center of curvature of the boundary surface (joint surface) **2** between the image plane side surface of the first lens element **111** and the object side surface of the transparent body **112** is set as R**2**.

The radius of the center of curvature of the boundary surface (joint surface) **3** between the image plane side surface of the transparent body **112** and the object side surface of the second lens element **113** is set as R**3**.

The radius of the center of curvature of the image plane side surface (concave surface) **4** of the second lens element **113** is set as R**4**.

The radius of the center of curvature of the object side surface (number five) **1** of the third lens element **121**B is set as R**5**.

The radius of the center of curvature of the boundary surface (joint surface) **6** between the image plane side surface of the third lens element **121**B and the object side surface of the second transparent body **122**B is set as R**6**.

The radius of the center of curvature of the boundary surface (joint surface) **7** between the image plane side surface of the second transparent body **122**B and the object side surface of the fourth lens element **123**B is set as R**7**.

The radius of the center of curvature of the image plane side surface **8** of the fourth lens element **123**B is set as R**8**.

The radius of the center of curvature of the object side surface **9** of the fifth lens element **133** is set as R**9**.

The radius of the center of curvature of the boundary surface (joint surface) **10** between the image plane side surface of the fifth lens element **133** and the object side surface of the third transparent body **134** is set as R**10**.

The radius of the center of curvature of the boundary surface (joint surface) **11** between the image plane side surface of the third transparent body **134** and the object side surface of the sixth lens element **135** is set as R**11**.

The radius of the center of curvature of the image plane side surface **12** of the sixth lens element **135** is set as R**12**.

The radii of the center of curvature R**2**, R**3**, R**6**, R**7**, R**10** and R**11** of the surfaces **2**, **3**, **6**, **7**, **10** and **11** are infinite (INFINITY).

Moreover, as shown in FIG. **11**, the distance on an optical axis OX between the surfaces **1** and **2**, the distance being the thickness of the first lens element **111**, is set as d**1**, and the distance on the optical axis OX between the surfaces **2** and **3**, the distance being the thickness of the transparent body **112**, is set as d**2**.

The distance on the optical axis OX between the surfaces **3** and **4**, the distance being the thickness of the second lens element **113**, is set as d**3**, and the distance on the optical axis OX between the image plane side surface **4** of the second lens element **113** and the object side surface **5** of the third lens element **121**B is set as d**4**.

The distance on the optical axis OX between the surfaces **5** and **6**, the distance being the thickness of the third lens element **121**B, is set as d**5**, and the distance on the optical axis OX between the surfaces **6** and **7**, the distance being the thickness of the second transparent body **122**B, is set as d**6**.

The distance on the optical axis OX between the surfaces **7** and **8**, the distance being the thickness of the fourth lens element **123**B, is set as d**7**, and the distance on the optical axis OX between the image plane side surface **8** of the fourth lens element **123**B and the object side surface **9** of the fifth lens element **133** is set as d**8**.

The distance on the optical axis OX between the surfaces **9** and **10**, the distance being the thickness of the fifth lens element **133**, is set as d**9**, and the distance on the optical axis OX between the surfaces **10** and **11**, the distance being the thickness of the third transparent body **13**, is set as d**10**.

The distance on the optical axis OX between the surfaces **11** and **12**, the distance being the thickness of the sixth lens element **135**, is set as d**11**, and the distance between the image plane side surface **12** of the sixth lens element **135** and the image plane **140** is set as d**12**.

Example 3 will be shown below with specific numerical values of the imaging lens. In Example 3, the surface numbers shown in FIG. **11** are assigned to the lens elements glass substrates (transparent bodies), and the imaging plane **140** constituting an imaging unit of the imaging lens **100**B.

EXAMPLE 3

Tables 9, 10, 11 and 12 show numerical values of Example 3. The numerical values of Example 3 correspond to the imaging lens **100**B of FIG. **10**.

Example 3 is a design example for a 5-megapixel (Mage pixel) CMOS imager of ¼ size and 1.4 μm pitch.

Table 9 shows the radii of curvature (R: mm), distances (d: mm), refractive indices (nd), and variances (vd) of the lens elements, the glass substrates (transparent bodies), and the like, which correspond to the surface numbers of the imaging lens in Example 3.

TABLE 9

Example 3 Configuration Data				
Surface Number	R	d	nd	νd
1:	1.263	0.477	1.51	53.1
2:	INFINITY	0.400	1.52	64.2
3:	INFINITY	0.072	1.60	30.0
4:	4.054	0.601		
5:	−2.887	0.070	1.60	30.0
6:	INFINITY	0.401	1.52	64.2
7:	INFINITY	0.500	1.60	30.0
8:	−1.499	0.693		
9:	−1.440	0.070	1.60	30.0
10:	INFINITY	0.400	1.52	64.2
11:	INFINITY	0.457	1.60	30.0
12:	−1100.420	0.207		

Table 10 shows the fourth, sixth, eighth and tenth order aspheric coefficients of the surface **1** of the first lens element **111** that includes an aspheric surface in Example 3, the surface **4** of the second lens element **113**, the surface **5** of the third lens element **121**B, and the surface **8** of the fourth lens element **123**B.

Furthermore, shown are the fourth, sixth, eighth and tenth order aspheric coefficients of the surface **9** of the fifth lens element **133**, and the surface **12** of the sixth lens element **135**.

In Table 10, K represents a conic constant, A a fourth order aspheric coefficient, B a sixth order aspheric coefficient, C an eighth order aspheric coefficient, and D a tenth order aspheric coefficient, respectively.

TABLE 10

Example 3 Aspheric Data					
First Surface:	K: −1.112	A: 0.708E−01	B: 0.585E−01	C: −0.509E−01	D: 0.670E−01
Fourth Surface:	K: 3.763	A: 0.502E−01	B: 0.118E+00	C: −0.203E+00	D: 0.401E+00
Fifth Surface:	K: −5.693	A: −0.132E+00	B: −0.225E−01	C: 0.521E−01	D: −0.212E−01
Eighth Surface:	K: 0.123	A: 0.431E−01	B: −0.175E−01	C: 0.450E−01	D: −0.243E−02
Ninth Surface:	K: −5.282	A: −0.118E+00	B: 0.890E−01	C: −0.209E−01	D: 0.165E−02
Twelfth Surface:	K: −10.000	A: 0.307E−01	B: −0.315E−01	C: 0.773E−02	D: −0.659E−03

Table 11 specifically shows the focal length f, numerical aperture F, half angle of view ω, and lens length H of the imaging lens **100**B in Example 3.

Here, the focal length f is set to 3.67 [mm], the numerical aperture F to 2.1, the half angle of view ω to 31.4 deg, and the lens length H to 4.35 [mm].

TABLE 11

Example 3 Configuration Data
f (Focal Length) = 3.67 mm
F (Numerical Aperture) = 2.1
ω (Half Angle of View) = 31.4 deg
H (Total Lens Length) = 4.35 mm

Table 12 shows that the above conditional expressions (1) to (11) are satisfied in Example 3.

TABLE 12

Values of Conditional Expressions by Example	
Conditional Expression	Example 3
(1)	−3.03
(2)	−0.39
(3)	0.92
(4)	1.12
(5)	−0.66
(6)	31.4
(7)	53.1
(8)	30
(9)	2.1
(10)	1.18
(11)	0.21

As shown in Table 12, in Example 3, the bending factor qL**2** of the second lens group **120** is set to −3.03, and the condition defined in conditional expression (1) is satisfied.

The incident surface of the third lens **130** group (the paraxial quantity of the third lens group) RL**3S1**/f is set to −0.39, and the condition defined in conditional expression (2) is satisfied.

The focal length fg**1** of the first lens group **110** is set to 0.93, and the condition defined in conditional expression (3) is satisfied.

The combined focal length fg**2** of the second lens group **120** is set to 1.12, and the condition defined in conditional expression (4) is satisfied.

The combined focal length fg**3** of the fourth lens group **130** is set to −0.66, and the condition defined in conditional expression (5) is satisfied.

The half angle of view ω is set to 31.4, and the condition defined in conditional expression (6) is satisfied.

The Abbe number νE1 of the first lens element **111** is set to 53.1, and the condition defined in conditional expression (7) is satisfied.

The Abbe number νE2 of the second lens element **113** is set to 30, and the condition defined in conditional expression (8) is satisfied.

The F-number Fno of the lens system is set to 2.1, and the condition defined in conditional expression (9) is satisfied.

The optical length TT of the lens system is set to 1.18, and the condition defined in conditional expression (10) is satisfied.

The back focus length FB of the lens system is set to 0.21, and the condition defined in conditional expression (11) is satisfied.

FIG. **12** is an aberration diagram illustrating spherical aberration (chromatic aberration), astigmatism aberration, and distortion in Example 3. (A) in FIG. **12** represents the spherical aberration (chromatic aberration), (B) in FIG. **12** the astigmatism aberration, and (C) in FIG. **12** the distortion, respectively.

As can be seen from FIG. **12**, according to Example 3, the aberrations of a spherical surface, astigmatism and distortion are corrected excellently, and an imaging lens including an optical unit that is excellent in image forming performance can be obtained.

<4. Fourth Embodiment>

FIG. **13** is a view illustrating a configuration example of an imaging lens according to a fourth embodiment of the present invention.

An imaging lens **100**C according to the fourth embodiment shown in FIG. **13** basically has a similar configuration to that of the imaging lens **110** according to the first embodiment, and as shown below as Example 4, the set values such as parameters of the constituent elements are different.

In the imaging lens **100**C, each lens group is constructed as follows.

A first lens group **110**C has a first lens element **111** of a plano-convex shape and, for example, an Abbe number of 57.3, which is adhered to an object side of a glass plate equivalent to BK7, and a second lens element **113** of an Abbe number of 30 and a plano-concave shape, which is adhered to the opposite side.

Here, a diaphragm is realized by previously attaching a material having little transmission such as a chrome film to the object side of the glass substrate.

Similarly, an IR cut filter is also previously attached by vapor deposition onto the glass substrate.

From these, the chromatic aberration is corrected in the first lens group **110**C, and it is possible to have a structure that can easily remove the entire aberration.

The first lens group **110**C as a whole has a strong positive power and greatly contributes to shortening of an optical length.

A second lens group **120**C has characteristics of being formed of a plastic molded lens made out of polycarbonate of, for example, an Abbe number of 30, not being bent largely and having a positive power.

This is because especially the first lens group and the third lens group greatly contribute to aberration correction, and accordingly it becomes unnecessary to bend the second lens group **120**C.

Without large bending, it is possible to accurately perform AR coating, and ghosting and flare are unlikely to occur. It is possible to use not only a plastic molded lens but also a glass molded lens and a high heat resistant lens of injection molding.

A third lens group **130**C is constructed of a plastic molded lens made out of polycarbonate of, for example, an Abbe number of 30 or a heat resistant resin, has a large negative power and a large incident surface, and is bent to the object side.

The center of curvature comes close to the diaphragm and therefore the astigmatism aberration and the coma aberration are corrected excellently.

Moreover, since the shape does not deviate greatly from the spherical shape, it is possible to realize a bright lens that has few changes in astigmatism aberration with respect to an incident NA due to an image height.

Moreover, an outgoing side surface has a shape that is also bent substantially to the object side, and orients a convex shape to the image side, which is a structure where ghosting is unlikely to occur.

Moreover, the incidence angle of light on an imager is suppressed low up until the perimeter and desirable performance can be obtained as the characteristics of a camera.

Example 4 will be shown below with specific numerical values of the imaging lens. In Example 4, the surface numbers shown in FIG. **2** are assigned to the lens elements glass substrate (transparent body) and the imaging plane **140** constituting an imaging unit of the imaging lens **100**C.

EXAMPLE 4

Tables 13, 14, 15 and 16 show numerical values of Example 4. The numerical values of Example 4 correspond to the imaging lens **100**C of FIG. **13**.

Example 4 is a design example for a 5-megapixel (Mage pixel) CMOS imager of ¼ size and 1.4 μm pitch.

Table 13 shows the radii of curvature (R: mm), distances (d: mm), refractive indices (nd), and variances (νd) of the lens elements, the glass substrate (transparent body), and the like, which correspond to the surface numbers of the imaging lens in Example 4.

TABLE 13

Example 4 Configuration Data

Surface Number	R	d	nd	νd
1:	1.266	0.734	1.51	57.3
2:	INFINITY	0.500	1.52	64.2
3:	INFINITY	0.050	1.51	57.0
4:	3.142	0.609		
5:	60.544	0.835	1.59	30.0
6:	−2.867	0.373		
7:	−1.130	0.600	1.59	30.0
8:	−11.518	0.300		

Table 14 shows the fourth, sixth, eighth and tenth order aspheric coefficients of the surface **1** of the first lens element **111** that includes an aspheric surface in Example 4, the surface **4** of the second lens element **113**, the surface **5** of a third lens element **121**, and the surface **6** of the third lens element **121**.

Furthermore, shown are the fourth, sixth, eighth and tenth order aspheric coefficients of the surface **7** of a fourth lens element **131**, and the surface **8** of the fourth lens element **131**.

In Table 14, K represents a conic constant, A a fourth order aspheric coefficient, B a sixth order aspheric coefficient, C an eighth order aspheric coefficient, and D a tenth order aspheric coefficient, respectively.

TABLE 14

Example 4 Aspheric Data

First Surface:	K: 0.221E−2	A: −0.113E−01	B: 0.804E−02	C: −0.188E−01	D: 0.114E−01
Fourth Surface:	K: 3.358	A: 0.811E−01	B: −0.248E−01	C: 0.239E+00	D: −0.110E+00
Fifth Surface:	K: −10.00	A: −0.271E−01	B: −0.724E−01	C: 0.435E−01	D: −0.662E−01

TABLE 14-continued

Example 4 Aspheric Data					
Sixth surface:	K: 2.165	A: 0.597E−01	B: 0.132E−01	C: −0.230E−01	D: 0.480E−02
Seventh Surface:	K: −0.856	A: 0.732E−01	B: 0.925E−02	C: −0.587E−02	D: 0.849E−03
Eighth Surface:	K: 10.00	A: −0.246E−01	B: −0.248E−02	C: −0.139E−02	D: 0.319E−03

Table 15 specifically shows the focal length f, numerical aperture F, half angle of view ω, and lens length H of the imaging lens **100**B in Example 4.

Here, the focal length f is set to 3.61 [mm], the numerical aperture F to 2.9, the half angle of view ω to 31.4 deg, and the lens length H to 4.00 [mm].

TABLE 15

Example 4 Configuration Data
f (Focal Length) = 3.61 men
F (Numerical Aperture) = 2.9
ω (Half Angle of View) = 31.4 deg
H (Total Lens Length) = 4.00 mm

Table 16 shows that the above conditional expressions (1) to (11) are satisfied in Example 4.

TABLE 16

Values of Conditional Expressions by Example	
Conditional Expression	Example 4
(1)	−0.91
(2)	−0.31
(3)	0.93
(4)	1.29
(5)	−0.60
(6)	31.4
(7)	57.3
(8)	30
(9)	2.9
(10)	1.108
(11)	0.3

As shown in Table 16, in Example 4, the bending factor qL**2** of the second lens group **120** is set to −0.91, and the condition defined in conditional expression (1) is satisfied.

The incident surface of the third lens **130** group (the paraxial quantity of the third lens group) RL**3S1**/f is set to −0.31, and the condition defined in conditional expression (2) is satisfied.

The focal length fg**1** of the first lens group **110** is set to 0.93, and the condition defined in conditional expression (3) is satisfied.

The combined focal length fg**2** of the second lens group **120** is set to 1.29, and the condition defined in conditional expression (4) is satisfied.

The combined focal length fg**3** of the fourth lens group **130** is set to −0.60, and the condition defined in conditional expression (5) is satisfied.

The half angle of view ω is set to 31.4, and the condition defined in conditional expression (6) is satisfied.

The Abbe number νE1 of the first lens element **111** is set to 57.3, and the condition defined in conditional expression (7) is satisfied.

The Abbe number νE2 of the second lens element **113** is set to 30, and the condition defined in conditional expression (8) is satisfied.

The F-number Fno of the lens system is set to 2.9, and the condition defined in conditional expression (9) is satisfied.

The optical length TT of the lens system is set to 1.108, and the condition defined in conditional expression (10) is satisfied.

The back focus length FB of the lens system is set to 0.3, and the condition defined in conditional expression (11) is satisfied.

FIG. **14** is an aberration diagram illustrating spherical aberration (chromatic aberration), astigmatism aberration, and distortion in Example 4. (A) in FIG. **14** represents the spherical aberration (chromatic aberration), (B) in FIG. **14** the astigmatism aberration, and (C) in FIG. **14** the distortion, respectively.

As can be seen from FIG. **14**, according to Example 3, the aberrations of a spherical surface, astigmatism and distortion are corrected excellently, and an imaging lens including an optical unit that is excellent in image forming performance can be obtained.

FIG. **15** is a view illustrating the defocus characteristics of MTF from on-axis to 70% of an image height, viewed in 80 lps/mm of Example 4.

As can be seen from here, with a depth of field equal to or more than that of FIG. **1** of the three-group/three-element, the embodiment of the present invention has a total optical length as short as 4.0 mm while the three-group/three-element has a total optical length of 4.4 mm.

Consequently, it can be seen that the embodiment of the present invention is adaptable to an optical unit whose depth of field is deep and total optical length is short.

<5. Fifth Embodiment>

FIG. **16** is a view illustrating a configuration example of an imaging lens according to a fifth embodiment of the present invention.

An imaging lens **100**D according to the fifth embodiment shown in FIG. **16** has the configuration of a first lens group **110**D, the configuration being different from those of the other embodiments.

The first lens group **110**D is formed of a conjugate of a first lens element **111**D, a second lens element **112**D, a transparent body **113**D, and a third lens element **114**.

A second lens group **120**D is formed of one fourth lens element **121**D.

A third lens group **130**D is formed of one fifth lens element **131**D.

In the imaging lens **100**D, each lens group is constructed as follows.

The first lens group **110**D has the first lens element **111**D of a biconvex shape and, for example, an Abbe number of 57.3, and the second lens element **113**D of a plano-concave shape and an Abbe number of 30.0, which are adhered to an object side of a glass plate equivalent to BK7.

The third lens element **114** of a plano-concave shape and an Abbe number of 30.0 is adhered to the opposite side.

Here, a diaphragm is realized by previously attaching a material having little transmission such as a chrome film to the object side of the glass substrate.

Similarly, an IR cut filter is also previously attached by vapor deposition onto the glass substrate.

Here, the first lens element **111**D is constructed of a biconvex lens having a large Abbe number, and the second lens element **112**D is formed of a lens of a plano-concave shape and a smaller Abbe number than that of the first lens element.

Both of them construct a doublet structure to have a structure where chromatic aberration is eliminated more than a single structure.

From these, the chromatic aberration is corrected in the first lens group **110**D, and it is also possible to have a structure that can easily remove the entire aberration. The first lens group **110**D as a whole has a strong positive power and greatly contributes to shortening of an optical length.

The second lens group **120**D has characteristics of being constructed by glass molding with, for example, an Abbe number of 31, not being bent largely, and having a positive power.

This is because especially the first lens group and the third lens group greatly contribute to aberration correction, and accordingly it becomes unnecessary to bend the second lens group **120**D.

Without large bending, it is possible to accurately perform AR coating, and ghosting and flare are unlikely to occur. It is possible to use not only a plastic molded lens but also a glass molded lens and a high heat resistant lens of injection molding.

The third lens group **30**D is constructed of a plastic molded lens made out of polycarbonate or a heat resistant resin, and has a large negative power and a large incident surface, and is bent to the object side.

The center of curvature comes close to the diaphragm and therefore the astigmatism aberration and the coma aberration are corrected excellently.

Moreover, since the shape does not deviate greatly from the spherical shape, it is possible to realize a bright lens that has few changes in astigmatism aberration with respect to an incident NA due to an image height.

Moreover, an outgoing side surface has a shape that is also bent substantially to the object side, and orients a convex shape to the image side, which is a structure where ghosting is unlikely to occur.

Moreover, the incidence angle of light on an imager is suppressed low up until the perimeter and desirable performance can be obtained as the characteristics of a camera.

From these, a bright lens whose total optical length is short can be realized.

For example, an axial chromatic aberration is 13.7 μm in Example 1 while being suppressed up to 9.0 μm in the example.

In this manner, the embodiment of the present invention makes it possible to fabricate a camera module with a normal optical system having the resolution of a three-element lens configuration, and Fno 2.0, which is very bright, in a 5 megapixel band; however, it is useful to make the first lens group **110**D on the incident side a doublet for higher performance.

Hence, it is possible to realize a lens having performance corresponding to the resolution of a four-element configuration with a normal optical system and simultaneously being very bright as Fno 2.0.

FIG. **17** is a view illustrating surface numbers assigned to lenses constituting lens groups, a substrate, and a cover glass constituting an imaging unit of the imaging lens according to the fifth embodiment.

Specifically, a surface number of number one is assigned to an object side surface (convex surface) of the first lens element **111**D, and a surface number of number two to a boundary surface (joint surface) between an image plane side surface of the first lens element **111**D and an object side surface of the second lens element **112**D.

A surface number of number three is assigned to a boundary surface (joint surface) between an image plane side surface of the second lens element **112**D and an object side surface of the transparent body **113**D.

A surface number of number four is assigned to a boundary surface (joint surface) between an image plane side surface of the transparent body **113**D and an object side surface of the third lens element **114**D.

A surface number of number five is assigned to an image plane side surface (concave surface) of the third lens element **114**D.

A surface number of number six is assigned to an object side surface (concave surface) of the fourth lens element **121**D, and a surface number of number seven to an image plane side surface of the fourth lens element **121**D.

A surface number of number eight is assigned to an object side surface (concave surface) of the fifth lens element **131**D, and a surface number of number nine to an image plane side surface of the fifth lens element **131**D.

Moreover, as shown in FIG. **17**, in the imaging lens **100**D of the embodiment, the radius of the center of curvature of the object side surface (number one) **1** of the first lens element **111**D is set as R**1**.

The radius of the center of curvature of the boundary surface (joint surface) **2** between the image plane side surface of the first lens element **111**D and the object side surface of the second lens element **112**D is set as R**2**.

The radius of the center of curvature of the boundary surface (joint surface) **3** between the image plane side surface of the second lens element **112**D and the object side surface of the transparent body **113**D is set as R**3**.

The radius of the center of curvature of the boundary surface (joint surface) **4** between the image plane side surface of the transparent body **113**D and the object side surface of the third lens element **114**D is set as R**4**.

The radius of the center of curvature of the image plane side surface (concave surface) **5** of the third lens element **114**D is set as R**5**.

The radius of the center of curvature of the object side surface (concave surface) **6** of the fourth lens element **121**D is set as R**6**, and the radius of the center of curvature of the image plane side surface **7** of the third lens element **121**D as R**7**.

The radius of the center of curvature of the object side surface (concave surface) **8** of the fifth lens element **131**D is set as R**8**, and the radius of the center of curvature of the image plane side surface **9** of the fifth lens element **131**D as R**9**.

The radii of the center of curvature R**3** and R**4** of the surfaces **3** and **4** are infinite (INFINITY).

Moreover, as shown in FIG. **17**, the distance on an optical axis OX between the surfaces **1** and **2**, the distance being the thickness of the first lens element **111**D, is set as d**1**, and the distance on the optical axis OX between the surfaces **2** and **3**, the distance being the thickness of the second lens element **112**D, is set as d**2**.

The distance on the optical axis OX between the surfaces **3** and **4**, the distance being the thickness of the transparent body **113**D, is set as d**3**.

The distance on the optical axis OX between the surfaces **4** and **5**, the distance being the thickness of the third lens element **114**D, is set as d**4**, and the distance on the optical axis OX between the image plane side surface **5** of the third lens element **114**D and the object side surface **6** of the fourth lens element **121**D is set as d**5**.

The distance on the optical axis OX between the surfaces **6** and **7**, the distance being the thickness of the fourth lens element **121**D, is set as d**6**, and the distance on the optical axis OX between the image plane side surface **7** of the fourth lens element **121**D and the image plane side surface **8** of the fifth lens element **131**D is set as d**7**.

The distance on the optical axis OX between the surfaces **8** and **9**, the distance being the thickness of the fifth lens element **131**D, is set as d**8**, and the distance between the image plane side surface **9** of the fifth lens element **131**D and the image plane **140** is set as d**9**.

Table 18 shows the fourth, sixth, eighth and tenth order aspheric coefficients of the surface **1** of the first lens element **111** that includes an aspheric surface in Example 5, the surface **5** of the third lens element **114**D, the surface **6** of the fourth lens element **121**D, and the surface **7** of the fourth lens element **121**D.

Furthermore, shown are the fourth, sixth, eighth and tenth order aspheric coefficients of the surface **8** of the fifth lens element **131**D, and the surface **9** of the fifth lens element **131**D.

In Table 18, K represents a conic constant, A a fourth order aspheric coefficient, B a sixth order aspheric coefficient, C an eighth order aspheric coefficient, and D a tenth order aspheric coefficient, respectively.

TABLE 18

Aspheric Data of Example 5					
First Surface:	K: 0.197	A: −0.159E−01	B: −0.428E−02	C: −0.170E−02	D: −0.554E−02
Fifth Surface:	K: 6.623	A: 0.589E−01	B: −0.267E−03	C: 0.104E+00	D: −0.205E−01
Sixth surface:	K: −10.000	A: −0.382E−01	B: −0.164E−01	C: −0.924E−02	D: −0.723E−02
Seventh Surface:	K: 3.191	A: 0.114E−01	B: −0.344E−01	C: 0.163E−01	D: −0.301E−02
Eighth Surface:	K: −0.776	A: −0.234E−01	B: −0.609E−01	C: 0.548E−01	D: −0.119E−01
Ninth Surface:	K: −10.000	A: −0.536E−01	B: −0.461E−02	C: 0.397E−02	D: −0.539E−03

Example 5 will be shown below with specific numerical values of the imaging lens. In Example 5, the surface numbers shown in FIG. **17** are assigned to the lens elements glass substrate (transparent body) and the imaging plane **140** constituting an imaging unit of the imaging lens **100**F.

EXAMPLE 5

Tables 17, 18, 19 and 306 show numerical values of Example 5. The numerical values of Example 5 correspond to the imaging lens **100**D of FIG. **16**.

Example 4 is a design example for a 5-megapixel (Mage pixel) CMOS imager of ¼ size and 1.4 μm pitch.

Table 17 shows the radii of curvature (R: mm), distances (d: mm), refractive indices (nd), and variances (vd) of the lens elements, the glass substrate (transparent body), and the like, which correspond to the surface numbers of the imaging lens in Example 5.

TABLE 17

Example 5 Lens Configuration Data				
Surface Number	R	d	nd	vd
1:	1.336	0.755	1.51	57.3
2:	−6.356	0.040	1.60	30.0
3:	INFINITY	0.500	1.53	55.0
4:	INFINITY	0.050	1.60	30.0
5:	4.313	0.576		
6:	162.056	1.080	1.69	31.3
7:	−3.294	0.408		
8:	−1.460	0.600	1.59	30.0
9:	11.839	0.300		

Table 19 specifically shows the focal length f, numerical aperture F, half angle of view ω, and lens length H of the imaging lens **100**B in Example 5.

Here, the focal length f is set to 3.66 [mm], the numerical aperture F to 2.1, the half angle of view ω to 33.6 deg, and the lens length H to 4.31 [mm].

TABLE 19

Configuration Data of Example 5
f (Focal Length) = 3.66 mm
F (Numerical Aperture) = 2.1
ω (Half Angle of View) = 33.6 deg
H (Total Lens Length) = 4.31 mm

Table 20 shows that the above conditional expressions (1) to (11) are satisfied in Example 5.

TABLE 20

Values of Conditional Expressions by Example	
Conditional Expression	Example 5
(1)	−0.96
(2)	−0.40
(3)	0.98
(4)	1.27
(5)	−0.59
(6)	33.6
(7)	57.3
(8)	30.0
(9)	2.1
(10)	1.18
(11)	0.3

As shown in Table 20, in Example 5, the bending factor qL2 of the second lens group **120** is set to −0.96, and the condition defined in conditional expression (1) is satisfied.

The incident surface of the third lens **130** group (the paraxial quantity of the third lens group) RL3S1/f is set to −0.40, and the condition defined in conditional expression (2) is satisfied.

The focal length fg1 of the first lens group **110** is set to 0.98, and the condition defined in conditional expression (3) is satisfied.

The combined focal length fg2 of the second lens group **120** is set to 1.27, and the condition defined in conditional expression (4) is satisfied.

The combined focal length fg3 of the fourth lens group **130** is set to −0.59, and the condition defined in conditional expression (5) is satisfied.

The half angle of view ω is set to 33.6, and the condition defined in conditional expression (6) is satisfied.

The Abbe number νE1 of the first lens element **111** is set to 57.3, and the condition defined in conditional expression (7) is satisfied.

The Abbe number νE2 of the second lens element **113** is set to 30, and the condition defined in conditional expression (8) is satisfied.

The F-number Fno of the lens system is set to 2.1, and the condition defined in conditional expression (9) is satisfied.

The optical length TT of the lens system is set to 1.18, and the condition defined in conditional expression (10) is satisfied.

The back focus length FB of the lens system is set to 0.3, and the condition defined in conditional expression (11) is satisfied.

FIG. **18** is an aberration diagram illustrating spherical aberration (chromatic aberration), astigmatism aberration, and distortion in Example 5. (A) in FIG. **18** represents the spherical aberration (chromatic aberration), (B) in FIG. **18** the astigmatism aberration, and (C) in FIG. **18** the distortion, respectively.

As can be seen from FIG. **18**, according to Example 3, the aberrations of a spherical surface, astigmatism and distortion are corrected excellently, and an imaging lens including an optical unit that is excellent in image forming performance can be obtained.

<6. Sixth Embodiment>

FIG. **19** is a view conceptually illustrating wafer-level optics according to a sixth embodiment of the present invention.

A plurality of replica lenses is formed on and under a glass substrate **210** to form a first group **220** (**110**). A second group **230** (**120**) is also constructed similarly.

Next, the individual lens groups are diced out.

Moreover, a lens made out of a single glass material forms a third group **240** (**130**), and a diced piece of the first group **220** and the second group **230** is bonded to the third group **240** to assemble a lens.

The optical unit according to the embodiment described in detail above can be basically formed with the following characteristics.

As described above, conditional expressions (1) to (11) are common to the first to forth embodiments (Examples 1 to 4), and are appropriately adopted as necessary to realize more preferable image forming performance and a compact optical system, which are suitable for individual imaging elements or imaging apparatuses.

As describe above, the optical unit of the embodiment is basically constructed of the first lens group **110**, the second lens group **120** and the third lens group **130**.

The first lens group has replica lenses on and under a glass substrate, and includes the first lens element, the first transparent substrate, and the second lens element, which are arranged in order from the object side to the image plane side.

A glass plate equivalent to BK7 manufactured by Schott is used for the transparent substrate to manufacture at low cost, and light shielding means such as a chrome film is processed on the glass substrate to form a diaphragm.

Hence, the thickness is at an almost negligible level unlike those of a normal molded product or sheet, and therefore there is no ghost or flare caused by the thickness and no vignetting in the corners. Moreover, an IR cut filter is also attached to the glass substrate.

Consequently, an IR cut filter that is normally placed between a lens element and an imaging element becomes unnecessary. Accordingly, it is possible to shorten a back focus and therefore the degree of freedom of optical design increases, and it is possible to design with better optical characteristics.

Moreover, since these two parts can be attached to a glass substrate, it is possible to make an inexpensive and highly reliable device having a small number of parts.

Furthermore, different lens materials can be used for the first and second lens elements, and it is possible to fabricate an optical element that is more excellent in optical characteristics than the conventional three-group lens element.

Moreover, it is possible to make the outermost part of an effective optical system thinner if the first lens element is formed on the glass substrate to make a diaphragm under the first lens element than if being constructed of an existing glass molded lens or a plastic molded lens.

Also from this point, it is possible to improve optical characteristics.

Moreover, it is also possible to further make the first lens element a doublet lens, further reduce chromatic aberration, and further increase resolution.

The second lens group has the characteristic of not being bent largely.

This is because especially the first lens group and the third lens group greatly contribute to aberration correction, and accordingly it becomes unnecessary to bend the second lens group.

Without large bending, it is possible to accurately perform AR coating, and ghosting and flare are unlikely to occur. It is possible to use not only a plastic molded lens but also a glass molded lens and a high heat resistant lens of injection molding.

Moreover, it is also possible to use a HYBRID type using a glass substrate, and also in here, if the bending is little, the thickness of the lens can be made thin, which facilitates manufacture and therefore it becomes an advantage.

The third lens group has a large negative power and a large incident surface, and is bent to the object side. The center of curvature comes close to the diaphragm and therefore the astigmatism aberration and the coma aberration are corrected excellently.

Moreover, since the shape does not deviate greatly from the spherical shape, it is possible to realize a bright lens that has few changes in astigmatism aberration with respect to an incident NA due to an image height.

Moreover, an outgoing side surface has a shape that is also bent substantially to the object side, and orients a convex shape to the image side, which is a structure where ghosting is unlikely to occur.

Moreover, the incidence angle of light on an imager is suppressed low up until the perimeter and desirable performance can be obtained as the characteristics of a camera.

When a group is seen as a unit, power arrangement takes a configuration of positive, positive and negative, and the aberrations are corrected excellently, and an optical path length can be shortened.

Here, the first lens group is a lens in the hybrid (HYBRID) method, and therefore the first element and the second element can be constructed of different materials, and it is possible to remove chromatic aberration only with the first lens group.

Next, it is possible to construct the positive-power second lens group and the negative-power third lens group, both of them being made out of a glass material whose Abbe number is close to 30.

Moreover, unlike the conventional example, the third lens group does not deviate greatly from the spherical shape, even if being made bright, there are fewer changes in aberration due to an image height, and it is possible to make it a brighter lens.

A main object of the embodiments of the present invention is to provide an optical unit that is optimal to an especially bright, small and fixed-focus (FF) lens with high resolution.

It is generally known that the conventional three-group/three-element lens has a deep depth of field and is optimal to an FF lens.

However, if Fno is decreased, MTF suddenly deteriorates, and approximately Fno 2.4 is the limit. It is considered to adopt a four-group/four-element lens in order to further improve optical characteristics; however, the four-group/four-element lens has a shallow depth of field, and it is difficult to adopt one for an FF lens.

In the embodiment, it is possible to overcome these problems. Fno can be decreased to 2.1 or lower while having a deep depth of field similar to a three-group/three-element lens and can secure a high MTF, and naturally can be used for a dark lens.

All the three groups can be constructed of lenses in the hybrid (HYBRID) method or can be manufactured in a wafer form in a mixture of the hybrid (HYBRID) method and a casting (Casting) method.

Rather in the embodiment, the first lens group is made in a wafer form, is diced and is subsequently assembled with the second and third lens groups.

Otherwise, it is possible to adopt, as potent assembling methods, law of methods such as that the first and second lens groups are made in a wafer form, are diced and are subsequently assembled with the third lens group.

This is because with high pixel number camera modules using the three-group configuration, even if a plurality of modules is simultaneously made in a wafer form, there are large variations in defocus of the individual modules, and they end by being assembled with imaging elements after dicing; accordingly, there is little need to complete a final form in a wafer form.

Rather than that, in order to increase the yield of the first lens group, the first group is made in a wafer form and is assembled after dicing, and each of the third lens groups having a large amount of SAG is fabricated as a molded (Mold) lens to lower the degree of difficulty in manufacture and optimize the whole, and it is possible to decrease the costs.

Outlines of combinable configurations are listed below:

HYBRID+(mold or casting)+(mold or casting)
HYBRID+HYBRID (mold or casting)
HYBRID+HYBRID+HYBIRD
HYBRID+(mold or casting)+HYBRID

(Here, a molded lens may be a replica lens.)

(Moreover, HYBRID may include a doublet structure lens therein.)

According to the embodiment described above, it is possible to obtain the following effects.

According to the embodiment, there are advantages of both of wafer optics in the hybrid (Hybrid) method and an optical unit constructed of a lens made by a normal mold manufacturing method.

A diaphragm can be attached to a glass substrate of the first lens group, and the number of parts can be reduced, which enables cost reduction. Moreover, since unlike an external part, a diaphragm part is not thick, there is no cause of ghosting, and no vignetting in the corners and accordingly optical characteristics improves.

The thickness of the edge of the first lens group can be made thin. Optical characteristics can be improved.

An IR cut filter can also be attached to the glass substrate of the first lens group, and therefore the number of parts can be reduced, which enables cost reduction. Moreover, since an external IR cut filter is unnecessary, the back focus can be shortened, and the degree of freedom of lens design increases. Accordingly, it is possible to make a unit that is more excellent in optical characteristics.

Since wafer optics in the hybrid (HYBRID) method is used for the first lens group, it is possible to use materials having different Abbe numbers for the back and front sides.

Since no lens deviates greatly from the spherical shape, it is possible to have Fno on the bright side.

The curvature of the incident surface of the third lens group comes close to the diaphragm and therefore the astigmatism aberration and the coma aberration are corrected excellently. Moreover, the surface shape is not undulating. Even if this makes the lens bright, there are few changes in aberrations due to an image height, and it is possible to have Fno on the bright side.

The outgoing surface of the third lens group has a substantially convex shape with respect to the image plane. Accordingly, even if the reflection of the image plane (imager) is reflected on this surface, an image is not formed, and ghosting does not occur.

Moreover, the incidence angle of light incident on the imager does not increase on the perimeter, and the desirable characteristics of a camera are held.

The bending of the second lens group is not bent sharply; accordingly, it is possible to accurately add AR coating, and the cause of ghosting does not arise.

Moreover, glass molding can be used. It is possible to stop temperature characteristics.

In units of groups, the power configuration is positive, positive and negative, and in the first lens group, the first element having a positive power and a large Abbe number, and the second element having a negative power and a small Abbe number perform color correction. It is possible to construct the positive-power second lens group and the negative-power third lens group, both of them using glass materials whose Abbe numbers are substantially the same, to prevent chromatic aberration. Moreover, the negative power lens system comes last, and the optical path length can be shortened.

Since the third lens group that greatly contributes to the projection area can be constructed of a molded lens, it is possible to form a projection shape into a circle, the area of the module is small after dicing.

Moreover, in this case, it is possible to adjust focus with normal equipment by placement in a screw lens barrel, and it is possible to manufacture in a normal low-cost manufacturing process.

If the third lens group is assembled later, it is possible to bury the first lens groups closely in a wafer and increase the yield. Consequently, it is possible to reduce the cost as a whole.

There are advantages that the brightness is higher than that of the three-group configuration, and the depth of field is deeper than that of the four-group configuration.

In the case of having an equivalent Fno, the depth of field is equal to or more than that of the three-group/three-element and the total optical length can be shortened.

Consequently, it is possible to make a lens element that is small, bright and excellent in image forming characteristics, and has a deep depth of field at low cost. Especially, since the lens element is optimal to a fixed-focus optical system, and has a deep depth of field without an actuator, it is optimal also to products that are required to be highly reliable, such as mobile phones and vehicle-mounted, and is possible to be used in various fields.

Furthermore, it is useful to make the first lens on the incidence side a doublet lens in order to have high performance; accordingly, it is possible to construct an optical system whose chromatic aberration is further reduced, and it is possible to realize high brightness and resolution corresponding to the four-element configuration with a normal optical system.

The imaging lenses **100**, **100**A, **100**B, **100**C and **100**D having the characteristics described above can be applied as a lens for a digital camera that uses an imaging element such as a CCD or CMOS sensor, especially a camera mounted on a small electronic device such as a mobile phone.

<7. Seventh Embodiment>

FIG. **20** is a block diagram illustrating a configuration example of an imaging apparatus in which an imaging lens including an optical unit according to the embodiment is adopted.

As shown in FIG. **20**, an imaging apparatus **300** includes an optical system **310** according to the embodiment, to which the imaging lens **100**, **100**A, **100**B, **100**C or **100**D is applied, and an imaging device **320** to which a CCD or CMOS image sensor (solid-state imaging device) can be applied.

The optical system **310** guides incident light to an imaging plane including a pixel area of the imaging device **320** to form an image of a subject.

The imaging apparatus **300** further includes a drive circuit (DRV) **330** that drives the imaging device **320** and a signal processing circuit (PRC) **340** that processes an output signal of the imaging device **320**.

The drive circuit **330** includes a timing generator (not shown) that generates various timing signals including a start pulse and a clock pulse for driving a circuit in the imaging device **320**, and drives the imaging device **320** with a predetermined timing signal.

Moreover, the signal processing circuit **340** performs predetermined signal processing on an output signal of the imaging device **320**.

An image signal processed by the signal processing circuit **340** is recorded in a recording medium, for example, a memory. The image information recorded in the recording medium is hard copied by a printer or the like. Moreover, the image signal processed by the signal processing circuit **340** is shown as a moving image on a monitor including a liquid crystal display.

As described above, in an imaging apparatus such as a digital still camera, the imaging lens **100**, **100**A, **100**B, **100**C or **100**D is mounted as the optical system **310**, and accordingly, it is possible to realize a low power and high precision camera.

Reference Signs List

100, **100**A to **100**D Imaging lens
110, **110**A to **110**D First lens group
120, **120**A to **120**D Second lens group
130, **130**A to **130**D Third lens group
300 Imaging apparatus
310 Optical system
320 Imaging device
330 Drive circuit (DRV)
340 Signal processing circuit (PRC)

The invention claimed is:

1. An optical unit comprising, arranged in order from an object side to an image plane side:

a first lens group,

a second lens group; and

a third lens group,

wherein,

the first lens group includes, arranged in order from the object side to the image plane side, (a) a first lens element, (b) a first transparent body, and (c) a second lens element, and

a focal length fg**1** of the first lens group, a focal length fg**2** of the second lens group, and a focal length fg**3** of the third lens group satisfy the following conditional expressions:

$$0.5 \leq fg1/f \leq 1.5,$$

$$0.5 \leq fg2/f \leq 50, \text{ and}$$

$$-5 \leq fg3/f \leq -0.3,$$

where f is a total focal length.

2. The optical unit according to claim **1**, wherein a bending factor qL**2** of the second lens group satisfies the following conditional expressions:

$$-10 \leq qL2 \leq -0.4, \text{ and}$$

$$qL2 = (RL2S2 + RL2S1)/(RL2S2 - RL2S1),$$

where

RL**2S1** is a radius of curvature of an input side surface S**1** of the second lens group, and

RL**2S2** is a radius of curvature of an outgoing side surface S**2** of the second lens group.

3. The optical unit according to claim **1**, wherein a paraxial quantity of the third lens group satisfies the following conditional expression and the surface shape includes a concave shape:

$$-3 \leq RL3S1/f \leq -0.2,$$

where

RL**3S1** is a radius of curvature of an incidence side surface S**1** of the third lens group, and

f is a focal length of the lens system.

4. The optical unit according to claim **1**, wherein at least the third lens group is formed by being molded individually or in a wafer form and being subsequently diced to be assembled.

5. The optical unit according to 1, wherein each of the second and third lens groups includes only a single lens element.

6. The optical unit according to claim 1, wherein an angle of view satisfies the following conditional expression:

$$20 \leq \omega \leq 40$$

where ω is a half angle of view.

7. The optical unit according to 1, wherein an Abbe number νE1 of the first lens element and an Abbe number νE2 of the second lens element satisfy the following conditional expressions:

$$45 \leq \nu E1 \leq 90, \text{ and}$$

$$20 \leq \nu E2 \leq 60,$$

where

νE1 is the Abbe number of the first lens element, and

νE2 is the Abbe number of the second lens element.

8. The optical unit according to claim 1, wherein an F-number of the lens system satisfies the following conditional expression:

$$1.0 \leq Fno \leq 3.0.$$

9. The optical unit according to claim 1, wherein an optical length TT of the lens system satisfies the following conditional expression:

$$0.8 \leq TT/f \leq 1.5$$

where f is the total focal length.

10. The optical unit according to claim 1, wherein a back focus BF of the lens system satisfies the following conditional expression:

$$0.01 \leq BF \leq 0.6.$$

11. An optical unit comprising, arranged in order from an object side to an image plane side:

a first lens group;

a second lens group; and

a third lens group,

wherein

the first lens group includes, arranged in order from the object side to the image plane side, (a) a first lens element, (b) a first transparent body, and (c) a second lens element, the first lens element and the second lens element forming a doublet lens.

12. The optical unit according to claim 11, wherein the first lens element has a biconvex shape and the second lens element has a plano-concave shape, the first and second lens elements forming the doublet lens.

13. The optical unit according to claim 12, wherein an Abbe number of the first lens element is larger than an Abbe number of the second lens element.

14. An imaging apparatus comprising:

an imaging element; and

an optical unit for forming an image of a subject in the imaging element,

wherein,

(1) the optical unit includes, arranged in order from an object side to an image plane side, (a) a first lens group, (b) a second lens group, and (c) a third lens group, and

(2) the first lens group includes, arranged in order from an object side to an image plane side, (a) a first lens element, (b) a first transparent body, and a (c) second lens element, and

(3) a focal length fg1 of the first lens group, a focal length fg2 of the second lens group, and a focal length fg3 of the third lens group satisfy the following conditional expressions:

$$0.5 \leq fg1/f \leq 1.5,$$

$$0.5 \leq fg2/f \leq 50, \text{ and}$$

$$-5 \leq fg3/f \leq -0.3,$$

where f is a total focal length.

15. An imaging apparatus comprising:

an imaging element; and

an optical unit for forming an image of a subject in the imaging element,

wherein,

(1) the optical unit includes, arranged in order from an object side to an image plane side, (a) a first lens group, (b) a second lens group, and (c) a third lens group, and

(2) the first lens group includes, arranged in order from an object side to an image plane side, (a) a first lens element, (b) a first transparent body, and a (c) second lens element, the first lens element and the second lens element forming a doublet lens.

* * * * *